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NATIONAL
ELECTRIC LIGHT
ASSOCIATION

Twenty-seventh Convention
Boston, Mass.
May 24, 25, 26, '04

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NATIONAL

Electric Light

ASSOCIATION

TWENTY-SEVENTH CONVENTION

VOLUME I

Papers, Reports and Discussions

BOSTON, MASSACHUSETTS
May 24th, 25th, 26th, 1904

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1904

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ARNOLD, E. E. *Notes on the Internal-Combustion Engine as Applied to Central-Station Service:* Discussion of principle types in practice, as four-stroke cycle and two-stroke cycle, giving working diagrams of various forms, together with respective crank efforts. Methods of speed-governing considered. Various kinds of fuel gas considered, especially producer gas. Table of tests on Westinghouse engine given, with a discussion of the results. Advantage of gas engines over steam engines discussed. Many examples of existing plants described. Paper is illustrated by reproductions of photographs, diagrams, curves and tables.

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BARNES, WALTER I. *A Three-Wire, 500-Volt Lighting System:* An illustrated description of the plant of the Narragansett Electric Light Company. Author gives a short review of the improvement leading up to the 250-volt incandescent lamp. The Narragansett company is the first in America to use the 550-volt, direct-current, three-wire system effectively for arc and incandescent lighting and power distribution. Arc lamps used are of the twin-carbon inclosed

tion to International Electrical Congress. Action regarding inactive committees. Creation of a permanent committee on municipal ownership, also appointment of reporter for investigating the thawing of water pipes by electricity. Desirability of periodical meetings of executive committee, expenses of same to be met by association. 4 to 13.

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HANCOCK, W. P. *Underground Construction:* Author of this paper was awarded the Doherty gold medal. The complete construction of an underground system is described. Author assumes an imaginary line and deals with the various steps in its construction, from the preliminary survey to its operation. Data used are drawn from experience, and the figures given can be used in estimating cost of any similar line.

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HODGKINSON, FRANCIS. *Practical Notes on Steam Turbines:* The author describes the construction and action of the principal types of turbines. The high speed of the turbine has necessitated a modification in generator design, resulting in a type called turbo-generator. Alternating machines are best suited for this system. Especial adaptability of the inductor-generator. The economy of the turbine and advantage of high vacuum at fractional load. Suitability of the various types of condensers. Saving in foundation expense due to freedom from vibration. Examples of several installations are given. Illustrated by curves, photographs and diagrams.

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RHODES, SAMUEL G. *The Organization and Equipment of an Arc-Lamp Department:* Description of the arc-lamp department of the New York Edison company, giving experiences and data connected with this installation. Department is in charge of an arc-light engineer. Paper describes operation of the department from the time a contract is signed with a customer. The trimmer's duties, his record and report. Complaints and repairs and records kept of same. Employment of boys for turning on and off direct-current multiple lamps. Illustrated.

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First	Chicago, February 25, 26, 1885
Second	New York, August 18, 19, 20, 1885
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Fourth	Detroit, August 31, September 1, 2, 1886
Fifth	Philadelphia, February 15, 16, 17, 1887
Sixth	Boston, August 9, 10, 11, 1887
Seventh	Pittsburg, February 21, 22, 23, 1888
Eighth	New York, August 29, 30, 31, 1888
Ninth	Chicago, February 19, 20, 21, 1889
Tenth	Niagara Falls, August 6, 7, 8, 1889
Eleventh	Kansas City, February 11, 12, 13, 14, 1890
Twelfth	Cape May, August 19, 20, 21, 1890
Thirteenth	Providence, February 17, 18, 19, 1891
Fourteenth	Montreal, September 7, 8, 9, 10, 1891
Fifteenth	Buffalo, February 23, 24, 25, 1892
Sixteenth	St. Louis, February 28, March 1, 2, 1893
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Twenty-sixth	Chicago, May 26, 27, 28, 1903
Twenty-seventh	Boston, May 24, 25, 26, 1904

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Frederic Nicholls, Toronto, Canada

ACTIVE MEMBERS

ALABAMA

ANNISTON,	Anniston Electric and Gas Company
BIRMINGHAM,	Birmingham Railway, Light and Power Company
DEMOPOLIS,	Demopolis Electric Light and Power Company
MOBILE,	Mobile Light and Railroad Company
MONTGOMERY,	Montgomery Light and Water Power Company

ARIZONA

PHŒNIX,	Phœnix Light and Fuel Company
PRESCOTT,	The Prescott Electric Company

ARKANSAS

EUREKA SPRINGS,	Citizens' Electric Company
FORT SMITH,	Fort Smith Light and Traction Company
HOT SPRINGS,	Hot Springs Water Company
LITTLE ROCK,	Little Rock Railway and Electric Company
PINE BLUFF,	Pine Bluff Light and Water Company

CALIFORNIA

LOS ANGELES,	Edison Electric Company
	Pacific Light and Power Company
	The Los Angeles Electric Company
MARYSVILLE,	Marysville Gas and Electric Company
MONTEREY,	Monterey County Gas and Electric Company
ONTARIO,	Ontario Power Company
SACRAMENTO,	Sacramento Electric, Gas and Railway Company
SAN FRANCISCO,	San Francisco Gas and Electric Company
SAN LEANDRO,	Suburban Electric Light Company
STOCKTON,	Stockton Gas and Electric Company

COLORADO

ASPEN,	The Roaring Fork Electric Light and Power Company
BOULDER,	The Boulder Electric Light and Power Company
CAÑON CITY,	The Colorado Electric Power Company
COLORADO SPRINGS,	The Colorado Springs Electric Company
DENVER,	Denver Gas and Electric Company
	Mountain Electric Company
	United States Light and Traction Company
DURANGO,	The Durango Light and Power Company
FORT COLLINS,	The Larimer Light and Power Company
GEORGETOWN,	The United Light and Power Company
GOLDEN,	The Golden Illuminating Company

COLORADO—*Continued*

IDAHO SPRINGS,	The Cascade Electric Company
	The Consolidated Gem Mines Company, Electrical Department
LAMAR,	The Lamar Electric Company
LAS ANIMAS,	Las Animas Electric Company
LEADVILLE,	Leadville Gas and Electric Company
MANITOU,	The Manitou Electric Company
OURAY,	The Ouray Electric Light and Power Company
PUEBLO,	Pueblo and Suburban Traction and Lighting Company
TELLURIDE,	The Telluride Electric Light and Power Company
	The Telluride Power Company

CONNECTICUT

BRANFORD,	Branford Lighting and Water Company
BRIDGEPORT,	Connecticut Railway and Lighting Company
DANBURY,	Danbury and Bethel Gas and Electric Light Company
DANIELSON,	People's Light and Power Company
DERBY,	Derby Gas Company
HARTFORD,	Hartford Electric Light Company
LITCHFIELD,	The Litchfield Electric Light and Power Company
MERIDEN,	Meriden Electric Light Company
MYSTIC,	The Mystic Electric and Gas Light Company
NEW LONDON,	The New London Gas and Electric Company
NORWICH,	Norwich Gas and Electric Company
ROCKVILLE,	The Rockville Gas and Electric Company
SOUTH MANCHESTER,	South Manchester Light, Power and Tramway Company
STAMFORD,	Stamford Gas and Electric Company
SUFFIELD,	Village Water Company
THOMPSONVILLE,	Enfield Electric Light and Power Company
UNIONVILLE,	The Union Electric Light and Power Company
WESTPORT,	Westport Water and Electric Light Company

DELAWARE

WILMINGTON,	The Wilmington City Electric Company

DISTRICT OF COLUMBIA

WASHINGTON,	Potomac Electric Power Company

FLORIDA

KEY WEST,	Key West Electric Company
TAMPA,	Tampa Electric Company

GEORGIA

AMERICUS,	Americus Illuminating and Power Company
ATHENS,	Athens Electric Railway Company

GEORGIA—*Continued*

ATLANTA,	Georgia Railway and Electric Company
AUGUSTA,	Augusta Railway and Electric Company
COLUMBUS,	The Columbus Railroad Company
SAVANNAH,	Savannah Electric Company

HAWAII

HONOLULU,	Hawaïian Electric Company, Limited

IDAHO

BOISÉ,	Capital Electric Light, Motor and Gas Company
LEWISTON,	Lewiston Water and Power Company
MOSCOW,	Moscow Electric Light and Power Company
POCATELLO,	American Falls Power, Light and Water Company

ILLINOIS

ABINGDON,	Abingdon Electric Company
ALTON,	Alton Gas and Electric Company
BLOOMINGTON,	Bloomington and Normal Railway, Electric and Heating Company
CANTON,	People's Gas and Electric Light Company
CENTRALIA,	Centralia Gas and Electric Company
CHESTER,	The Chester Light, Water and Ice Company
CHICAGO,	Chicago Edison Company
	Chicago Sectional Electric Underground Company
	Commonwealth Electric Company
CLINTON,	Clinton Gas Company
DEKALB,	DeKalb-Sycamore Electric Company
DIXON,	Dixon Power and Lighting Company
EDWARDSVILLE,	Edwardsville Electric Light and Power Company
EVANSTON,	North Shore Electric Company
FREEPORT,	Freeport Railway, Light and Power Company
HILLSBORO,	Hillsboro Electric Light and Power Company
JACKSONVILLE,	Jacksonville Gas Light and Coke Company
JOLIET,	Economy Light and Power Company
MOLINE,	People's Power Company
NOKOMIS,	Nokomis Electric Light and Power Company
PEORIA,	Peoria Gas and Electric Company
PONTIAC,	Pontiac Light and Water Company
QUINCY,	The Independent Light and Power Company
ROCKFORD,	Rockford Edison Company
SPRINGFIELD,	Springfield Electric Light and Power Company
	The Capital Electric Company
STREATOR,	Streator Gas and Light Company
TAYLORVILLE,	Taylorville Electric Company
WARSAW,	Warsaw Electric Light Plant
WATSEKA,	Watseka Electric and Heat Company

INDIANA

ELKHART,	Elkhart Electric Company
ELWOOD,	Elwood Electric Light Company
EVANSVILLE,	Evansville Gas and Electric Light Company
FORT WAYNE,	Fort Wayne Electric Light and Power Company
GOSHEN,	The Hawks Electric Company
KOKOMO,	Kokomo, Marion and Western Traction Company
MADISON,	Madison Lighting Company
MARION,	Marion Light and Heating Company
NEW ALBANY,	United Gas and Electric Company
RICHMOND,	Richmond Light, Heat and Power Company
SOUTH BEND,	South Bend Electric Company
TERRE HAUTE,	Terre Haute Electric Company
WABASH,	The Wabash Electric Light Company

IOWA

CEDAR RAPIDS,	Cedar Rapids and Iowa City Railway and Light Company
DAVENPORT,	People's Light Company
DECORAH,	The Decorah Electric Light Company
DES MOINES,	Des Moines Edison Light Company
DUBUQUE,	Union Electric Company
IOWA CITY,	Iowa City Electric Light Company
KEOKUK,	Keokuk Electric Railway and Power Company
MASON CITY,	Brice Gas and Electric Company
MUSCATINE,	Citizens' Railway and Light Company
OTTUMWA,	Ottumwa Traction and Light Company
RED OAK,	Red Oak Electric Company
SIOUX CITY,	Sioux City Gas and Electric Company
WATERLOO,	Waterloo and Cedar Falls Gas and Electric Company

KANSAS

CLAY CENTER,	F. L. Williamson and Company
COLUMBUS,	The Columbus Electric Company
JUNCTION CITY,	The Electric Railway, Light and Ice Company
TOPEKA,	Edison Electric Illuminating Company of Topeka, Kansas

KENTUCKY

COVINGTON,	The Union Light, Heat and Power Company
LEXINGTON,	Lexington Railway Company
LOUISVILLE,	Louisville Lighting Company
PADUCAH,	The Paducah City Railway Company

LOUISIANA

LAKE CHARLES,	The Lake Charles Ice, Light and Water Works Company
NEW ORLEANS,	New Orleans and Carrollton Railway, Light and Power Company
SHREVEPORT,	Shreveport Gas, Electric Light and Power Company

MAINE

BANGOR,	Public Works Company
BRUNSWICK,	The Brunswick Electric Light and Power Company
OAKLAND,	Oakland Electric Company
PORTLAND,	Consolidated Electric Light Company of Maine
	Portland Lighting and Power Company
SKOWHEGAN,	Skowhegan Electric Light Company
WATERVILLE,	Waterville and Fairfield Railway and Light Company

MARYLAND

BALTIMORE,	The United Electric Light and Power Company
BEL AIR,	The Bel Air Electric Company
CRISFIELD,	Crisfield Ice Manufacturing Company
FREDERICK,	Frederick Electric Light and Power Company
HAVRE DE GRACE,	The Havre de Grace Electric Company

MASSACHUSETTS

AMHERST,	Amherst Gas Company
ATTLEBORO,	Attleboro Steam and Electric Company
BEVERLY,	Beverly Gas and Electric Company
BOSTON,	The Edison Electric Illuminating Company of Boston
BROCKTON,	Edison Electric Illuminating Company of Brockton
BROOKLINE,	Brookline Gas Light Company
CAMBRIDGE,	Cambridge Electric Light Company
CHELSEA,	Chelsea Gas Light Company
CLINTON,	Clinton Gas Light Company
COHASSET,	The Cohasset Electric Company
FALL RIVER,	Fall River Electric Light Company
FITCHBURG,	Fitchburg Gas and Electric Light Company
GARDNER,	Gardner Electric Light Company
GREAT BARRINGTON,	Great Barrington Electric Light Company
HYDE PARK,	Hyde Park Electric Light Company
LAWRENCE,	Lawrence Gas Company
LEE,	Lee Electric Company
LEICESTER,	Rawson Light and Power Company
LEXINGTON,	Lexington Gas and Electric Company
LOWELL,	The Lowell Electric Light Corporation
LYNN,	Lynn Gas and Electric Company
MALDEN,	Malden Electric Company
MARLBORO,	Marlborough Electric Company
NEW BEDFORD,	New Bedford Gas and Edison Light Company
NEWTON,	Newton and Watertown Gas Light Company
NORTH ADAMS,	North Adams Gas Light Company
PALMER,	Central Massachusetts Electric Company
PITTSFIELD,	Pittsfield Electric Company
PLYMOUTH,	Plymouth Electric Light Company
REVERE,	Suburban Gas and Electric Company
SALEM,	Salem Electric Lighting Company.

MASSACHUSETTS—*Continued*

SOUTHBRIDGE,	Andrew F. Hall
SPRINGFIELD,	United Electric Light Company
WEBSTER,	Webster Electric Company
WESTBORO,	Westboro Gas and Electric Company
WEST SOMERVILLE,	Somerville Electric Light Company
WINCHENDON,	Winchendon Electric Light and Power Company
WOBURN,	Woburn Light, Heat and Power Company
WORCESTER,	Worcester Electric Light Company

MEXICO

MONTEREY,	Monterey Light and Power Company

MICHIGAN

ADRIAN,	The Citizens' Light and Power Company
ALPENA,	Alpena Electric Light Company
ANN ARBOR,	Washtenaw Light and Power Company
BIG RAPIDS,	W. E. Donley Electric Light and Power Company
BROOKLYN,	Brooklyn Electric Light Company
CHEBOYGAN,	Cheboygan Electric Light and Power Company
CORUNNA,	Shiawassee Light and Power Company
DETROIT,	Peninsular Electric Light Company
HOUGHTON,	Houghton County Electric Light Company
IONIA,	Ionia Electric Company
JACKSON,	Jackson Light and Power Company
KALAMAZOO,	Kalamazoo Valley Electric Company
MANCELONA,	Mancelona Electric Light and Power Company
PLAINWELL,	Arnold and Brownell Electric Company
PORT HURON,	Port Huron Light and Power Company
SAGINAW,	Bartlett Illuminating Company
ST. JOSEPH,	Benton Harbor and St. Joseph Electric Railway and Light Company
SAULT STE. MARIE	Edison Sault Electric Company

MINNESOTA

ALBERT LEA,	Albert Lea Light and Power Company
CROOKSTON,	Crookston Water Works, Power and Light Company
DULUTH,	Duluth General Electric Company
FARIBAULT,	The Faribault Gas and Electric Company
LITTLE FALLS,	The Little Falls Water Power Company of Minnesota
MINNEAPOLIS,	The Minneapolis General Electric Company
MONTEVIDEO,	Montevideo Electric Light and Power Company
PIPESTONE,	Pipestone Electric Light, Heat and Power Company
RED WING,	Red Wing Gas and Electric Company
ST. CLOUD,	Light, Heat, Transit and Public Service Company
ST. PAUL,	Edison Electric Light and Power Company of St. Paul
WINONA,	Winona Railway and Light Company

MISSISSIPPI

COLUMBUS,	Columbus Light and Power Company
INDIANOLA,	Indianola Light, Ice and Coal Company
MERIDIAN,	Meridian Light and Railway Company
VICKSBURG,	Vicksburg Railway and Light Company

MISSOURI

DE SOTO,	Consumers' Electric Light and Power Company
EXCELSIOR SPRINGS,	The Excelsior Springs Light, Power, Heat and Water Company
JOPLIN,	Southwest Missouri Light Company
KANSAS CITY,	The Kansas City Electric Light Company
MONETT,	Monett Electric Light, Power and Ice Company
ST. JOSEPH,	St. Joseph Railway, Light, Heat and Power Company
ST. LOUIS,	The Laclede Gas Light Company
	The Laclede Power Company of St. Louis
	Union Electric Light and Power Company
SPRINGFIELD,	Springfield Gas and Electric Company
WASHINGTON,	Tibbe Electric Company

MONTANA

ANACONDA,	The Anaconda Copper Mining Company, Electric Light and Railway Department
BIG TIMBER,	Bigtimber Electric Light and Power Company
BILLINGS,	Billings Water Power Company
BUTTE,	Butte Electric and Power Company
GREAT FALLS,	Boston and Great Falls Electric Light and Power Company
HELENA,	Helena Light and Traction Company
KALISPELL,	Big Fork Electric Power and Light Company
MISSOULA,	Missoula Light and Water Company

NEBRASKA

BEATRICE,	Beatrice Electric Company
KEARNEY,	The Northwestern Electric, Heat and Power Company
LINCOLN,	Lincoln Gas and Electric Light Company
OMAHA,	Omaha Electric Light and Power Company

NEW HAMPSHIRE

CONCORD,	Concord Electric Company
DOVER,	United Gas and Electric Company
FRANKLIN FALLS,	The Franklin Light and Power Company
KEENE,	Keene Gas and Electric Company
MANCHESTER,	Manchester Traction, Light and Power Company
NASHUA,	Nashua Light, Heat and Power Company
NEWPORT,	Newport Electric Light Company
PENACOOK,	Penacook Electric Light Company
PORTSMOUTH,	Rockingham County Light and Power Company

NEW JERSEY

Asbury Park,	Atlantic Coast Electric Company
Atlantic City,	The Atlantic Electric Light and Power Company
Dover,	Dover Electric Light Company
Egg Harbor,	Atlantic County Electric Company
Hackensack,	The Gas and Electric Company of Bergen County
Lambertville,	Hunterdon Electric Company
Long Branch,	Consolidated Gas Company of New Jersey
Newark,	Public Service Corporation of New Jersey, Electric Department
Washington,	Washihgton Electric Light Company

NEW MEXICO

Santa Fé,	Santa Fé Water and Light Company

NEW YORK

Albion,	Albion Power Company
Alexandria Bay,	St. Lawrence International Electric Railroad and Land Company
Amsterdam,	Edison Electric Light and Power Company
Auburn,	Auburn Light, Heat and Power Company
Binghamton,	Binghamton Light, Heat and Power Company
Brooklyn,	Edison Electric Illuminating Company of Brooklyn
Buffalo,	Buffalo General Electric Company
Cazenovia,	The Union Electric Company
Cooperstown,	The Clinton Mills Power Company
Dundee,	Dundee Electric Light Plant
Elmira,	Elmira Water, Light and Railroad Company
Far Rockaway,	Queens Borough Gas and Electric Company
Fishkill-on-Hudson	Citizens' Railroad, Light and Power Company
Fulton,	Fulton Light, Heat and Power Company
Glens Falls,	Hudson River Water Power Company
Gloversville,	Fulton County Gas and Electric Company
Greenwich,	Consolidated Electric Company
Hoosick Falls,	Hoosick Falls Electric Company
Ithaca,	Ithaca Electric Light and Power Company
Jamestown,	Jamestown Lighting and Power Company
Keeseville,	Keeseville Electric Company
Kingston,	Kingston Gas and Electric Company
Liberty,	Liberty Light and Power Company
Little Falls,	Herkimer County Light and Power Company
Lockport,	The Lockport Gas and Electric Light Company
Long Island City,	New York and Queens Electric Light and Power Company
Lyons,	Wayne County Electric Company
Mount Vernon,	Westchester Lighting Company
Newburgh,	Newburgh Light, Heat and Power Company

NEW YORK—*Continued*

NEW YORK CITY,	New York Edison Company
	United Electric Light and Power Company
NIAGARA FALLS,	Buffalo and Niagara Falls Electric Light and Power Company
	The Niagara Falls Hydraulic Power and Manufacturing Company
	The Niagara Falls Power Company
NORWICH,	Norwich Gas and Electric Company
NYACK,	Rockland Light and Power Company
ONEIDA,	Madison County Gas and Electric Company
ONEONTA,	Oneonta Light and Power Company
OVID,	Ovid Electric Company
PEEKSKILL,	Peekskill Lighting and Railroad Company
PORT JERVIS,	Port Jervis Light, Power, Gas and Railroad Company
POTSDAM,	The Potsdam Electric Light and Power Company
POUGHKEEPSIE,	Poughkeepsie Light, Heat and Power Company
RICHFIELD SPRINGS,	Richfield Springs Electric Light and Power Company
ROCHESTER,	Rochester Gas and Electric Company
ROSLYN,	Nassau Light and Power Company
SARANAC LAKE,	Saranac Lake Light, Heat and Power Company
SCHENECTADY,	Schenectady Railway Company
SOUTHAMPTON,	The Southampton Electric Light Company
SYRACUSE,	Syracuse Lighting Company
TONAWANDA,	Tonawanda Power Company
TUXEDO PARK,	Tuxedo Electric Light Company
UTICA,	Utica Gas and Electric Company
WATERTOWN,	Watertown Electric Light Company

NORTH CAROLINA

ASHEVILLE,	Asheville Electric Company
CHARLOTTE,	Catawba Power Company
DURHAM,	Durham Traction Company
HENDERSON,	Henderson Lighting and Power Company
RALEIGH,	The Raleigh Electric Company
WINSTON-SALEM,	The Fries Manufacturing and Power Company

NORTH DAKOTA

GRAND FORKS,	Grand Forks Gas and Electric Company

OHIO

AKRON,	The Northern Ohio Traction and Light Company
ALLIANCE,	Alliance Gas and Electric Company
CANTON,	Canton Light, Heat and Power Company
CINCINNATI,	The Cincinnati Gas and Electric Company
CLEVELAND,	The Cleveland Electric Illuminating Company
COLUMBUS,	The Columbus Railway and Light Company
DEFIANCE,	People's Gas and Electric Company

OHIO—*Continued*

ELYRIA,	The Citizens' Gas and Electric Company
LANCASTER,	The Lancaster Electric Light Company
LEIPSIC,	Leipsic Electric Light, Heat and Power Company
LIMA,	The Lima Electric Railway and Light Company
LISBON,	The New Lisbon Gas Company
MASSILLON,	Massillon Light, Heat and Power Company
PORTSMOUTH,	Portsmouth Street Railroad and Light Company
SALEM,	The Salem Electric Light and Power Company
SPRINGFIELD,	The Springfield Light and Power Company
STEUBENVILLE,	The Steubenville Traction and Light Company
TOLEDO,	The Toledo Railways and Light Company
WARREN,	The Warren Electric Light and Power Company
YOUNGSTOWN,	Youngstown Consolidated Gas and Electric Company
ZANESVILLE,	The Zanesville Railway, Light and Power Company

OKLAHOMA

GUTHRIE,	The New Electric and Gas Light Company
SHAWNEE,	The Shawnee Light and Power Company

ONTARIO

LONDON,	The London Electric Company, Limited
OTTAWA,	The Ottawa Electric Company
TORONTO,	Toronto and Niagara Power Company

OREGON

ASHLAND,	Ashland Electric Power and Light Company
PORTLAND,	Portland General Electric Company
SALEM,	Citizens' Light and Traction Company
SUMPTER,	The Sumpter Light and Water Company of Sumpter Oregon

PENNSYLVANIA

ALTOONA,	The Edison Electric Illuminating Company of Altoona
BETHLEHEM,	The Bethlehem Electric Light Company
BRADFORD,	Bradford Electric Light Company
BRISTOL,	The Bristol Electric Light and Power Company
CARBONDALE,	Lackawanna Valley Electric Light and Power Supply Company
CARLISLE,	The Carlisle Gas and Water Company
CONNELLSVILLE	The Electric Company
DANVILLE,	Standard Electric Light Company
DOYLESTOWN,	Doylestown Electric Company
EASTON,	Easton Power Company
FRANKLIN,	Franklin Electric Company
GREENVILLE,	People's Electric Light Company
LEWISTOWN,	Lewistown Electric Light Company

PENNSYLVANIA—*Continued*

MORTON,	Faraday Heat, Power and Light Company
NEW CASTLE,	New Castle Electric Company
OIL CITY,	Citizens' Light and Power Company
PHILADELPHIA,	The American Railways Company
	The Electric Company of America
	The Philadelphia Electric Company
PHILIPSBURG,	The Philipsburg Electric Light, Gas, Power and Heating Company
PHŒNIXVILLE,	Phœnix Gas and Electric Company
PITTSBURG,	Allegheny County Light Company
PITTSTON,	Citizens' Electric Illuminating Company
READING,	Metropolitan Electric Company
RENOVO,	The Renovo Edison Light, Heat and Power Company
SCRANTON,	Scranton Illuminating, Heat and Power Company
TOWANDA,	Towanda Electric Illuminating Company
WARREN,	Warren Electrical Light Company
WASHINGTON,	The Washington Electric Light and Power Company
WAYNESBORO,	Waynesboro Electric Light and Power Company
WAYNESBURG,	Waynesburg Electric Light and Power Company
WEST CHESTER,	The Edison Electric Illuminating Company
WILLIAMSPORT,	Lycoming Electric Company
YORK,	Edison Electric Light Company

QUEBEC

MONTREAL,	Montreal Light, Heat and Power Company
QUEBEC,	Quebec-Jacques Cartier Electric Company
	The Quebec Railway, Light and Power Company
SHERBROOKE,	The Sherbrooke Power, Light and Heat Company

RHODE ISLAND

NEWPORT,	Newport and Fall River Street Railway and Lighting Company
PAWTUCKET,	Pawtucket Electric Company
PROVIDENCE,	Narragansett Electric Lighting Company
WOONSOCKET,	Woonsocket Electric Machine and Power Company

SOUTH CAROLINA

CHARLESTON,	Charleston Consolidated Railway, Gas and Electric Company
COLUMBIA,	Columbia Electric Street Railway, Light and Power Company
DARLINGTON,	Darlington Light and Water Company
GEORGETOWN,	Georgetown Electric Company

SOUTH DAKOTA

LEAD,	Belt Light and Power Company

TENNESSEE

BRISTOL,	Bristol Gas and Electric Company
CHATTANOOGA,	Chattanooga Electric Company
COLUMBIA,	Columbia Water and Light Company
KNOXVILLE,	The Knoxville Electric Light and Power Company
MEMPHIS,	Memphis Consolidated Gas and Electric Company
NASHVILLE,	Nashville Railway and Light Company

TEXAS

BEAUMONT,	Beaumont Ice, Light and Refrigerating Company
CLEBURNE,	The Cleburne Gas and Electric Company
CORSICANA,	Corsicana Gas and Electric Company
DALLAS,	Dallas Electric Light and Power Company
	Dallas Ice Factory, Light and Power Company
EL PASO,	International Light and Power Company
GAINESVILLE,	Merchants' Electric Light and Power Company
HOUSTON,	Houston Lighting and Power Company
MARSHALL,	Arkansas and Texas Consolidated Ice and Coal Company
PARIS,	Paris Light and Power Company
SAN ANTONIO,	San Antonio Gas and Electric Company
TAYLOR,	Taylor Electric Light Company
WAXAHACHIE,	Waxahachie Gas and Electric Company

UTAH

SALT LAKE CITY,	Utah Light and Railway Company

VERMONT

BELLOWS FALLS,	The Fall Mountain Electric Light and Power Company
BENNINGTON,	Bennington Water Power and Light Company
BRANDON,	Neshobe Electric Company
BURLINGTON,	Burlington Light and Power Company
FAIR HAVEN,	Fair Haven Electric Company
MIDDLEBURY,	Middlebury Electric Company
MONTPELIER,	Consolidated Lighting Company
RUTLAND,	Rutland City Electric Company
ST. JOHNSBURY,	St. Johnsbury Electric Company
VERGENNES,	The Vergennes Electric Company

VIRGINIA

LYNCHBURG,	Lynchburg Traction and Light Company
RICHMOND,	Virginia Passenger and Power Company
ROANOKE,	Roanoke Railway and Electric Company

WASHINGTON

ABERDEEN,	Gray's Harbor Electric Company
DAYTON,	Dayton Electric Light and Power Company

WASHINGTON—*Continued*

EVERETT,	Everett Railway and Electric Company
OLYMPIA,	Olympia Light and Power Company
SEATTLE,	Snoqualmie Falls Power Company
	The Seattle Electric Company
SPOKANE,	The Washington Water Power Company
WALLA WALLA,	Northwestern Gas and Electric Company

WEST VIRGINIA

BLUEFIELD,	East River Electric Company
CHARLESTON,	Kanawha Water and Light Company
DAVIS,	Davis Electric Light Company
PARKERSBURG,	Parkersburg, Marietta and Inter-Urban Railway Company
SISTERSVILLE,	Sistersville Electric Light and Power Company
WHEELING,	The Wheeling Electrical Company

WISCONSIN

ANTIGO,	Antigo Light, Heat and Power Company
DELAVAN,	Delavan Light and Fuel Company
EAU CLAIRE,	Eau Claire Light and Power Company
FOND-DU-LAC,	Eastern Wisconsin Railway and Light Company
JANESVILLE,	Janesville Electric Company
KENOSHA,	Kenosha Gas and Electric Company
LA CROSSE,	La Crosse Gas and Electric Light Company
MADISON,	Madison Gas and Electric Company
MENOMONIE,	Menomonie Electric Light and Power Company
MERRILL,	Merrill Railway and Lighting Company
OCONTO,	W. A. Holt
PORT WASHINGTON,	The Wisconsin Chair Company
RHINELANDER,	Rhinelander Lighting Company
SPARTA,	O. I. Newton's Sons Company
WAUKESHA,	Waukesha Gas and Electric Company
WAUPACA,	Waupaca Electric Light and Railway Company
WAUSAU,	Wausau Electric Company

WYOMING

CHEYENNE,	Cheyenne Light, Fuel and Power Company

ASSOCIATE MEMBERS

AMPERE, N. J.,	Crocker-Wheeler Company
AUBURN, N. Y.,	McIntosh, Seymour and Company
BALTIMORE, MD.,	Electrical Material Company
BOSTON, MASS.,	Albert and J. M. Anderson Manufacturing Company
	Electric Gas Lighting Company
	Frank Ridlon Company
	Herbert S. Potter
	Massachusetts Chemical Company
	McKenney and Waterbury Company
	Pettingell-Andrews Company
	Stuart-Howland Company
	The Elliott Addressing Machine Company
	The Simplex Electrical Company
	Thomas C. Wales
BRIDGEPORT, CONN.,	Bryant Electric Company
BUFFALO, N. Y.,	Charles F. Johnson
CHELSEA, MASS.,	American Circular Loom Company
CHICAGO, ILL.,	Chicago Fuse Wire and Manufacturing Company
	Chicago Insulated Wire Company
	Electric Appliance Company
	George Cutter Company
	Gregory Electric Company
	Western Electric Company
	Western Electrician
CINCINNATI, OHIO,	Bullock Electric Manufacturing Company
	Triumph Electric Company
CLEVELAND, OHIO,	Adams-Bagnall Electric Company
	Buckeye Electric Company
	National Carbon Company
	The United States Carbon Company
COVINGTON, KY.,	Hemingray Glass Company
DAYTON, OHIO,	National Cash Register Company
DETROIT, MICH.,	The Phelps Company
EAST PITTSBURG, PA.,	The Westinghouse Machine Company
FORT WAYNE, IND.,	Fort Wayne Electric Works
FOSTORIA, OHIO,	Crouse-Tremaine Carbon Company
GREAT BARRINGTON, MASS.,	Stanley Instrument Company
JONESBORO, IND.,	Indiana Rubber and Insulated Wire Company
KEOKUK, IA.,	Garton-Daniels Company
LOCKPORT, N. Y.,	American District Steam Company
MATTEAWAN, N. Y.,	The Green Fuel Economizer Company
MILWAUKEE, WIS.,	National Electric Company

MYSORE, INDIA,	B. D. Nath
NEWARK, N. J.,	Baker and Company
	Weston Electrical Instrument Company
NEW BEDFORD, MASS.,	W. S. Hill Electric Company
NEWBURYPORT, MASS.,	Chase-Shawmut Company
NEW YORK CITY,	Alberger Condenser Company
	American Conduit Company
	American-Diesel Engine Company
	American Vitrified Conduit Company
	Atlantic Insulated Wire and Cable Company
	Bryan-Marsh Company
	Converse D. Marsh
	De La Vergne Machine Company
	Electrical Review Publishing Company
	Electrical Testing Laboratories
	Electricity Newspaper Company
	Ford, Bacon and Davis
	Franklin H. Kalbfleisch Company
	General Electric Company
	General Incandescent Arc Light Company
	Gould Storage Battery Company
	H. B. Camp Company
	Holophane Glass Company
	Hugo Reisinger
	H. W. Johns-Manville Company
	India Rubber and Gutta Percha Insulating Company
	International Steam Pump Company
	J. A. and W. Bird Company
	Jeremiah J. Kennedy
	J. G. White Company
	J. Henry Hallberg
	John A. Roebling's Sons Company
	Manhattan Electrical Supply Company
	McGraw Publishing Company
	National Conduit and Cable Company
	New York Insulated Wire Company
	Osburn Flexible Conduit Company
	Rossiter, MacGovern and Company
	Sanderson and Porter
	Sprague Electric Company
	Standard Vitrified Conduit Company
	The *Cassier Magazine* Company
	The *Central Station*
	The Dale Company
	The Electric Carriage Call Company, Incorporated
	The Okonite Company, Limited
	The Phœnix Glass Company

NEW YORK CITY,	The Standard Paint Company
PHILADELPHIA, PA.,	Alfred F. Moore
	Electric Storage Battery Company
	James H. Dawes
	R. D. Wood and Company
PITTSBURG, PA.,	Doubleday-Hill Electric Company
	Nernst Lamp Company
	Standard Underground Cable Company
	The Pittsburgh Reduction Company
	Westinghouse Electric and Manufacturing Company
PITTSFIELD, MASS.,	Stanley Electric Manufacturing Company
PROVIDENCE, R. I.,	American Electrical Works
	New England Butt Company
ST. CATHERINES, ONTARIO,	The Packard Electric Company, Limited
ST. LOUIS, MO.,	Columbia Incandescent Lamp Company
	The Emerson Electric Manufacturing Company
	Wagner Electric Manufacturing Company
SCHENECTADY, N. Y.,	William T. Taylor
SPRINGFIELD, MASS.,	Munder Electrical Works
SYRACUSE, N. Y.,	Crouse-Hinds Electric Company
	Pass and Seymour
TRENTON, N. J.,	De Laval Steam Turbine Company
WARREN, OHIO,	New York and Ohio Company
WEST NEW BRIGHTON, N.Y.,	C. W. Hunt Company
WORCESTER, MASS.,	American Steel and Wire Company

OFFICERS AND EXECUTIVE COMMITTEE

Officers

Charles L. Edgar	President
S. B. Livermore	First Vice-President
J. W. Lieb, Jr.	Second Vice-President
Ernest H. Davis	Secretary and Treasurer
H. Billings	Asst. Secretary and Treasurer
George F. Porter	Master of Transportation

Executive Committee

Elected at the Twenty-fourth to serve until the close of the Twenty-seventh Convention

Charles L. Edgar   C. C. Howell
D. P. Robinson

Elected at the Twenty-fifth to serve until the close of the Twenty-seventh Convention

J. H. Perkins (in place of Charles L. Edgar, promoted)
C. F. Hewitt (in place of C. C. Howell, deceased)

Elected at the Twenty-fifth to serve until the close of the Twenty-eighth Convention

A. C. Dunham   P. G. Gossler
H. T. Hartman

Elected at the Twenty-sixth to serve until the close of the Twenty-ninth Convention

Louis A. Ferguson   Harry Bottomley
Alex Dow

Elected at the Twenty-seventh to serve until the close of the Thirtieth Convention

Samuel Scovil   A. J. De Camp
W. F. White

COMMITTEES

TO REPORT TO THE TWENTY-SEVENTH CONVENTION

Committee on Finance
H. H. FAIRBANKS, Chairman
W. S. BARSTOW — E. F. PECK

Committee on Standard Rules for Electrical Construction and Operation
WILLIAM BROPHY, Chairman
JAMES I. AYER — LOUIS A. FERGUSON

Committee on Standard Candle-Power of Incandescent Lamps
DR. LOUIS BELL, Chairman
JAMES I. AYER — CALVIN W. RICE

Committee on Legislative Policy
SAMUEL INSULL, Chairman
H. M. ATKINSON — SAMUEL SCOVIL
ERNEST H. DAVIS — CHARLES R. HUNTLEY

Committee on Photometric Values of Arc Lamps
HENRY L. DOHERTY, Chairman
W. E. GOLDSBOROUGH — CHARLES P. MATTHEWS

Committee on Analysis of Flue Gases
HENRY L. DOHERTY, Chairman
W. L. ABBOTT — PROFESSOR DUGALD JACKSON

Committee on Uniform Accounting
GUY L. TRIPP, Chairman
W. F. HAM — W. A. ANTHONY

Committee on Relations Between Manufacturers and Central Station Companies
HENRY L. DOHERTY, Chairman
A. C. DUNHAM — LOUIS A. FERGUSON

Committee on Relations with Kindred Organizations
JAMES I. AYER, Chairman
J. W. LIEB, JR. — W. E. GOLDSBOROUGH

Committee on Purchased Electric Power in Factories
WILLIAM H. ATKINS, Chairman
S. MORGAN BUSHNELL, — GEORGE W. BRINE

Committee for Investigation of Steam Turbines
W. C. L. EGLIN, Chairman
FREDERIC SARGENT — A. C. DUNHAM

Committee on District Heating
E. F. McCABE, Chairman
C. R. MAUNSELL — D. F. McGEE

Reporter on Lost and Unaccounted-for Current	C. W. HUMPHREY
Reporter on Advertising Methods	LARUE VREDENBURGH
Reporter on Decorative and Sign Lighting	ARTHUR WILLIAMS
Editor of Progress	T. COMMERFORD MARTIN
Editor Wrinkle Department	CHARLES H. WILLIAMS
Editor Question Box	H. T. HARTMAN

ORDER OF BUSINESS

TUESDAY, May 24, 1904.

FIRST SESSION, 10.45 A. M.

1. Announcements
2. Address of President Edgar
3. Report—Committee on Progress. T. COMMERFORD MARTIN, Reporter
4. Paper—"A Three-Wire Five-Hundred-Volt Lighting System." By WALTER I. BARNES
5. Paper—"The Luminous or Flaming Arc." By WELLES E. HOLMES

SECOND SESSION, 2.30 P. M.

1. Report—Committee on Uniform Accounting. GUY L TRIPP, Chairman
2. Report—Committee on Legislative Policy. SAMUEL INSULL, Chairman
3. Paper—"A One-Hundred-Mile Transmission Line." By ROBERT HOWES
4. Report—Committee on Standard Candle-Power of Incandescent Lamps. DR. LOUIS BELL, Chairman
5. Paper—"The Advisability and Methods of Grounding the Neutral on High-Potential Alternating-Current Generators." By GEORGE N. EASTMAN
6. Paper—"The Organization and Equipment of an Arc-Lamp Department." By SAMUEL G. RHODES
7. Paper—"Electric Heating and the Field It Offers Central Stations." By JAMES I. AYER
8. Report—Lost and Unaccounted-for Current. C. W. HUMPHREY, Reporter

MINUTES

OPENING OF THE CONVENTION

The twenty-seventh convention of the National Electric Light Association was held at the Hotel Vendome, Boston, May 24, 25, 26 and 27, 1904. The meeting was called to order by President Edgar at a quarter before eleven o'clock, Tuesday morning, May 24. The first order of business was the reading of communications from gentlemen especially invited to attend the convention.

ANNOUNCEMENTS

The secretary read letters from the following gentlemen who signified their intention of attending the convention:

Frederic Nicholls, Toronto, Canada, Past-President of the Association.

Thomas D. Lockwood, Boston, Honorary Member.

Henry S. Pritchett, President Massachusetts Institute of Technology, Boston.

Professor I. N. Hollis, Harvard University, Cambridge, Mass.

Professor A. E. Kennelly, Harvard University.

Professor William L. Hooper, Tufts College, Mass.

Professor Louis Duncan, Massachusetts Institute of Technology.

F. P. Fish, President American Telephone and Telegraph Company, Boston.

Letters and telegrams of regret at not being able to be present were read from the following-named gentlemen:

S. B. Livermore, First Vice-President, Winona, Minn.

J. W. Lieb, Jr., Second Vice-President, New York city.

Past-President Samuel Duncan, Atlanta, Ga.

Past-President Charles R. Huntley, Buffalo, N. Y.

Past-President E. A. Armstrong, Camden, N. J.

Past-President M. J. Francisco, Rutland, Vt.

Past-President C. H. Wilmerding, Chicago.

Past-President Samuel Insull, Chicago.

Past-President Alden M. Young.

Thomas A. Edison, Orange, N. J., Honorary Member.

Charles F. Brush, Cleveland, Ohio, Honorary Member.

Edward L. Nichols, Ithaca, N. Y., Honorary Member.

George S. Bowen, Elgin, Ill., Honorary Member.

C. O. Baker, Jr., New York city, Honorary Member.

W. L. Bowers, President Iowa State Electric Association, Davenport, Iowa.

C. L. Wakefield, Dallas, Texas.

A tally-ho ride for the ladies attending the convention was

announced for the afternoon, with the request that their names be registered at the Information Bureau before eleven o'clock.

Announcement was made that the Cooper Hewitt Company had arranged to take photographs in its parlor at the hotel by the Cooper Hewitt light, and an invitation was extended to the members to form parties and groups and be photographed without charge at some time during the convention.

President Edgar then read the following address:

ADDRESS OF PRESIDENT

To the Members of the National Electric Light Association:

It is with peculiar pleasure that I welcome you to this city. It is now seventeen years since this association met in Boston, and although I agree with my predecessors that the duty of the president of this association should be that of executive officer rather than historian, I can not resist the opportunity to make a few comparisons between the year 1887, when this association met at the Parker House, in this city, and the present year.

It was my pleasure to attend that convention as a guest of our old friend, Captain Brophy, and I have a somewhat distinct recollection of the meetings and of the entertainments. I know it was with considerable anticipation that I looked forward to the visit to the works of the Thomson-Houston Company, in Lynn, then rated as one of the largest works of its kind in this country, and yet the number of men employed in the entire works at that time was not as great as of those now employed in almost each one of its dozen departments.

At that time, too, the Boston Edison company, that, with its friends and associates in Boston, is one of those to welcome you here to-day, was the proud possessor of one small station, with a total load connected to its overhead system equal to the fortnightly growth of the present year. In those days, too, the horse-cars made their weary way along the Tremont-street mall of the Boston Common. To-day, not only the horses but the cars and the tracks have disappeared, and under this same mall, now made handsome by the disappearance of the tracks, is located and operated the first electrically-operated subway; one of the finest in this country, or, in fact, in the world.

And so I might go on for an hour, showing that during these seventeen years other things besides the electric-lighting business have shown tremendous progress; yet, after looking at all these other things and forming a conclusion as to what the rate of progress has been, we are astounded when we turn our gaze upon our own business, as represented by the

members of this association distributed throughout the United States and Canada. The number of electric-light stations has increased during these seventeen years more than nine-fold. Naturally, the membership of this association has not grown in proportion, but the fact that there are now upon our rolls 588 members, as compared with only 158 at that time, is a matter for sincere congratulation. The wonderful work done by my two immediate predecessors in getting new members into this association stands by itself. The growth this year, as the result of their work, has been rather slow. At the same time, the association has had a healthy and steady increase in membership, and I feel satisfied that it will continue in at least as great a ratio as during the past year.

Speaking now, for a moment, as one of the representatives of the electrical interests in this city, I beg to call your attention to the entertainment programme submitted by that committee. This programme has been prepared with great care, and, although extensive and varied, does not in any way conflict with the business for which we have come together. Six business sessions of the association have been arranged for, as shown by the official programme, and we are planning to have, with your assistance, three days of hard and conscientious work. Before proceeding to the consideration of this programme, there are a number of matters to which, as chief executive officer of this association, I should like to call your attention.

Some months ago, the question of a Union Engineering Building in New York was brought officially to the attention of this association. As is well known, Mr. Andrew Carnegie offered to give $1,000,000 to the four associations composing the electrical, the mechanical, the mining and the civil engineers of this country, together with the Engineers' Club of New York, for the purpose of putting up a Union Engineering Building, which should be the most comprehensive affair of its kind in the world. After due consideration, all of the organizations named, with the exception of the American Institute of Civil Engineers, decided to take part. It being generally understood that Mr. Carnegie had in mind an enterprise covering all branches of engineering life, great doubt existed in the minds of those interested as to whether or not he would be willing to go on, in

view of the declination of the Civil Engineers to take their share. As most of you may know, he has not only decided to erect this building for the remaining associations, but has increased the sum from $1,000,000 to $1,500,000. The space that it was intended to allot to the Civil Engineers is to be fitted up with modern office accommodations, and this association, as well as a number of others of the same general character, was asked if it would be willing to consider taking its permanent offices in this building. I conferred with a number of gentlemen connected with this association and familiar with its history, and informed the committee that I thought that the National Electric Light Association would undoubtedly consider with great favor the question of locating its permanent offices in their building. To those of you who are familiar with the present unsatisfactory location of our secretary's office, the proposed arrangement will, I think, appeal with great force. Personally, I am strongly of the opinion that the location of our offices under these circumstances in the quiet of the up-town district and in an engineering atmosphere will be a great benefit to all concerned.

The time has come when it seems desirable to make a somewhat radical change in the by-laws of our association. When it was organized some nineteen years ago, the industry consisted of a large number of small companies, located throughout the country. Almost without exception, these companies were confined each to its own city; in fact, there were a number of cities, especially those of the larger size, that had a number of competing companies. As time went on, consolidations took place, either by the purchase of a local company by a syndicate or holding company or by the actual amalgamation of competing or of adjoining companies. This has at the present time been carried on to such an extent that in some sections of the country all of the small companies have now been obliterated and one large corporation now covers the territory and does the entire work. A most striking example of this kind comes under my own personal observation. The Boston Edison company has taken the place of fifteen local lighting companies, all of whom were eligible for membership in our association. Under the regulations of this state it is necessary actually to wind up these local companies, not only in a business but in a corporate sense, and a number of them have therefore had to resign from the association. Within the

next year or two there will be only one company left and the actual membership in the association will be cut down from seven to one. This is going on all over the country and is a matter of serious concern for the future of the association. The matter has been discussed at considerable length by the executive committee, and numerous suggestions have been made for overcoming the difficulty. These have been put in concrete form by your secretary and will be submitted to the association in executive session. Speaking generally, the remedy suggested is to have another class of membership, consisting of individuals called junior active members, to be elected under some sort of supervision from the active member with whom they are connected in business and paying as dues an amount in keeping with their privileges. I trust that this matter will be given serious consideration by the members of the association within the next two or three days, so that a conclusion can be arrived at at the executive session on Thursday.

The electric-lighting industry of this country has in the past, in certain definite directions, been under somewhat serious disadvantages because of the lack of a comprehensive and correct directory of our industry. In most other lines of work it has been possible for manufacturers, investors, or inquirers generally, to find out something about the industry in which they were interested. This want was brought especially to my attention some time during the early part of the year. One of the various circular letters issued periodically by our assistant secretary was sent out over my name and mailed from Boston. The number of letters returned to me undelivered was astonishing, and I came to the conclusion that all the existing lists were worse than useless. About this time our attention was called to the prospect of this work being taken up by one of our own members and put on a par with the publications of other industries of like character. I think that we should give our earnest support to this enterprise; incidentally because it is carried on by one of our own members, but primarily and selfishly because we are interested in having it a success.

During the year, a somewhat disturbing occurrence took place in connection with the proposed participation that this association was to take in the affairs of the International Electrical Congress. Both at the Cincinnati convention and a year

later at Chicago, invitations were extended to this association to meet at St. Louis to take part in the congress. Through an unfortunate combination of circumstances, this invitation was overlooked in making out the final programme. The committee of your association that has in charge the relations that exist between this association and kindred organizations, took the matter up and after long and somewhat complicated conferences advised me that it was its wish that the association should accept a new invitation from the congress, inviting us to prepare three papers and to send the authors as delegates to the congress. The invitation in this form was accepted and the executive committee is about to choose these delegates, and I have every reason to hope that an announcement of their names and their subjects can be made before the adjournment of this convention. The work of the congress is truly international in its character, papers having been promised by some of the most noted scientists in the world, both in this country and abroad, and we are, for this reason, extremely anxious that our representation at the congress shall be in keeping with the standing of this association.

Until I became president of your association I had no suspicion of the vast amount of work carried on at your permanent offices in New York. Under the efficient direction of your assistant secretary, a large and varied correspondence is kept up with the member companies, an average of over ten letters per day being written on all sorts of subjects. In addition to this, various compilations have been made during the year and most of these have been forwarded to the members from time to time. The office is now engaged upon various other reports, notices of which will be given to you at the proper time. In short, we have a thorough and businesslike organization, capable of taking up and intelligently discussing almost any subject of interest to the members of the association.

Some time during the winter, it was suggested to me by one of the members of the executive committee that there must be a vast fund of available information in the records of the association which was practically useless because of the lack of an index. The matter was taken up at once, and there has been prepared a complete index of the papers and reports presented to this association since its organization, indexed and cross-in-

dexed in various ways. It is intended to publish this as a separate volume for distribution with the proceedings of this convention. I think that none of you who has not specially looked into this subject realizes the great amount of information that is locked up in the proceedings of our conventions but that will be available at a moment's notice when this index is published.

A month or two ago, Mr. C. O. Baker decided that he would be unable to attend this convention and therefore tendered his resignation as master of transportation. Mr. Baker has been identified with this office for so many years, and has managed its affairs so satisfactorily, that many of you have not realized either the time or the ability that he has given to the affairs of this association. I would therefore suggest that an appropriate resolution be passed, recognizing the work of this efficient officer. I was fortunate in finding Mr. George F. Porter, so long and so closely indentified with all of you, able and willing to take up this work, and it was therefore with great satisfaction that I appointed him to the vacant office.

The programme to which I invite your attention has, I think, a number of papers and reports of great interest to this association. This year we have made a special effort to have the papers printed in advance. Of the twenty-eight papers upon the programme, all have been printed, and twenty-three were mailed about a week ago to the home addresses of those intending to attend the convention, and I think it is an appropriate time for me to express personally my sincere thanks to the authors of these various papers and reports for their promptness and willingness to assist me in carrying out this scheme. The result is that we hope to be enabled to give much more attention than usual to the discussion of these papers, as they have, I hope, been read and considered by the delegates before leaving home. I therefore have to suggest that some of the papers be read only by title and others abstracted in a somewhat brief manner. This is the practice among organizations of this character, and although it is an innovation in this association I think the experiment is one worthy of consideration.

Another matter to which I wish to call your attention is the great delay that has taken place in the past years in the publication of our records. I have followed up this matter during the past year with great interest and considerable im-

patience. Remarks made at the Chicago convention in May have remained uncorrected for three months. In an effort to prevent this, I asked that this year the arrangement for stenographic work be made on the basis of a corrected proof before the adjournment of the convention. I therefore most earnestly ask each gentleman taking part in the discussions to make a determined effort to correct his remarks before leaving Boston. This can be done in each case in a few moments and will enable us to send out our book while the matter is fresh in the minds of our members. I do not want to try to accomplish the impossible, but I am satisfied that months can be saved by a systematic effort on the part of each delegate to assist the secretary's office in this matter.

All of the committees recommended by your two preceding presidents have been appointed and have made reports, which are in print and before you. The report of the committee on steam turbines is of the greatest importance, and it so appealed to one of the members of the committee that he undertook a further investigation of this subject abroad. Upon his return, only one month ago, he turned over to the committee such a wealth of material and data that it was impossible to get it in type in advance of the opening of the convention. It has been my pleasure to be present at one or two of the recent meetings of this committee, and I can assure you that the material contained in the report is of the greatest value to you all.

The *Question Box* and the *Wrinkles* are both papers worthy of your careful attention. The dividing line between these two departments is very hazy, and I am not at all sure that they should not be operated in connection with each other. This is a matter for the incoming administration to decide.

During the year, the question of advertising has been taken up on a scale of considerable magnitude by a number of our larger member companies. The experience gained by these companies ought to be of great value, even to the small members, and the paper of your advertising reporter, together with its accompanying samples of advertising matter, will, I think, be a subject of much interest to you all.

The gold medal offered two years ago by past-President Doherty for the best paper on underground construction was not awarded last year. In February of this year, notices were

sent out to members of the association, and to the public generally, that this competition was open. A number of papers have been presented and considered by a committee of three distinguished engineers, who were appointed for that purpose. They have come to their conclusion and will announce their decision at the morning session to-morrow.

When I took the presidency last year, I discovered upon the records a number of committees that had not reported for some years. There seemed to be no clear distinction in the minds of any one as to the difference between yearly and standing committees. I therefore called upon all of these old committees either to report or to suggest their discharge. I hope to leave to my successor the privilege of appointing or reappointing committees only upon subjects that are active at the present time.

The work of the association is so well distributed among its various committees and reporters that it seems to me there are very few things that have not been covered. I do think, however, that we should have a strong, permanent committee upon the subject of municipal ownership. This subject is a perennial one and although, perhaps, no more serious to-day than during the last half dozen years, it is certainly a subject of great importance and one which, handled by a strong committee and headed by some member who would take the initiative, would be of great assistance to the member companies of the association.

The extremely cold weather of the past year has also brought out prominently a novel use of the service of the electric companies. I refer to the thawing of water pipes. Unfortunately, I have been disappointed in getting a paper on this subject for this convention. Although we may not have a winter such as the past for a number of years, I think the experience that has been gained by some of our companies during the past year should be made use of, and I would therefore suggest the appointment of a reporter to take up this subject, compile such information as he can obtain as to the recent experiences of our member companies, and distribute it to the members some time during the coming summer or early fall.

The position of the president of this association is a hard

one, and yet I do not know but that, from the very nature of our organization, it must be so. The association and its business is continuous. The president, sometimes taken from the executive committee and sometimes from the ranks, finds himself upon the adjournment of the annual convention at the head of an extensive organization, of which he knows very little. It takes months to absorb and understand the really great and comprehensive work that this association is carrying on. As soon as he gets this into his head he is called upon to prepare for the next convention, and then, when it is all over, he lays down the duties of his office with a sigh of relief and a feeling of commiseration for his successor. I do not know that this can be helped. I think that our theory of having three members of the executive committee elected each year, thus making that body continuous and having it the governing one of the association, is good, but, as a matter of fact, the executive committee has never had any reason to believe that it had much to do with the executive work of the association. I think we should have a general understanding that the executive committee is intended for work; that it should get together at least once in three months and be a connecting link between the president and the sentiment of the association as represented by the members. For this purpose I think that the executive committee should be chosen with some reference to geographical location and with considerable reference to the size of the companies that it represents. Then, in order to make it easy and possible for its members to attend the periodic meetings of the committee, an arrangement should be authorized for meeting the necessary expenses of these meetings. This matter has been discussed by the executive committee during the past year, and I hope that the committee will have some definite suggestions to offer in the report that it will make at the executive session on Thursday.

Even if this can be accomplished, I realize that the difficulty is fundamental. We must look to our permanent officers to keep the work of the association going in the right direction. It devolves upon them to instruct the incoming administration as to the precedents and policies of the past and in general to keep the permanent policy of the organization before the mind of each new executive, leaving to the latter

the privilege of bringing to the office and to the work the strength of his own personality, and thus, by a mixture of the old and the new, building up an organization that will stand distinct and unique among its confreres.

MR. HENRY L. DOHERTY (Denver): It has been customary to refer the address of the president to a committee for the consideration of the recommendations it contains. The address you have just heard contains as many valuable suggestions for the future welfare of the association as any of the addresses we have heretofore heard, if not more. This is a comprehensive effort to put the affairs of the association in better shape, and I move that the secretary be instructed to appoint a committee to confer upon the address of the president and report upon the same.

(The motion was carried, and the secretary subsequently appointed the following-named gentlemen as a committee on the president's address: Henry L. Doherty, Denver, chairman; George W. Brine, Atlanta; H. T. Hartman, Philadelphia.)

THE PRESIDENT: Before proceeding with the regular programme there are one or two things that it might perhaps be well to say; we say them every year. When we adjourn to-day for luncheon I want you, gentlemen, to decide at what hour we shall come together again. I will agree that we shall meet at that time. It may be hard on the gentleman who has to read the first paper to call the meeting promptly, but unless we do this we shall not have sufficient time to consider all the papers.

The first paper on the programme is on a subject that was new last year. It was such a success that it is repeated this year, and I have no doubt that it will be repeated indefinitely at our future meetings. I take pleasure in introducing Mr. T. Commerford Martin, of New York, who will present a report on Progress.

MR. MARTIN: Mr. President—I understand from the remarks that have been made regarding the papers being in type and sent to the nembers of the association a week ago, that it will hardly be necessary to read the paper in full. Mine was one of the papers in type. The members have there-

fore had a full week in which to determine the value of its contents, and I hardly think it necessary to take up your time in presenting merely an abstract.

The paper deals primarily with statistics of the art and of the industry, indicating the growth that our art is making, and presenting for the first time before this association the figures compiled by the United States Census Office, for which I have the honor of acting as special expert agent. It is the first time that the figures of the electric-light industry in any country in the world have been compiled, and I am very proud of the fact that in this instance, as in so many others of the kind, our Government takes the lead. Following that, I present comparisons between our country, England, Germany and Spain, and I also present some figures in regard to the consumption of current in Europe and regarding the prices obtained for service, including incidentally such figures as a price of $225 and $240 per arc lamp in Paris—figures that I respectfully commend to you for quotation the next time you are up against the municipal-ownership proposition.

My paper next deals with the advances, improvements and inventions being made with respect to electric lighting technically, and gives briefly some data and a few facts with regard to the Nernst lamp, the Cooper Hewitt mercury-vapor lamp, the osmium lamp and the magnetite lamp. With regard to the last mentioned, however, a paper will be presented shortly following my own. This lamp, I notice, is referred to as the "luminous or flaming arc," and I think you will agree with me—especially those of you who met here in this city seventeen years ago—that we can at last congratulate ourselves upon being able to present to the public a luminous arc.

My paper then gives some data with regard to the subject of electric heating, having reference especially to the plant—which is the largest in the world—that has been installed in the Government Printing Office in Washington, where electric heating is used for practically every purpose that can be conceived of in connection with the art of typography and of binding. Reference is also made in the paper to the interesting use of electric heating that has been introduced at Harvard by our past-president, Mr. Ayer, in connection with the refreshments for the students there.

I believe this summarizes briefly, but quite sufficiently, the main points in the report that the committee has deemed worth while to present to you. There were a number of subjects that I had set aside for discussion and in regard to which I had accumulated data and information, but I have been glad to know that our president, by his energy and well-directed intelligence, had been able to secure from well-known men definite papers dealing with these topics. It therefore seemed quite unnecessary for me to take up subjects that are more fully treated by more competent men.

The following is Mr. Martin's report:

REPORT OF THE COMMITTEE ON PROGRESS

The central-station industry of the United States has enjoyed since this association last met, in Chicago, another year of marked advance and prosperity. Although the period has been one of uncertainty and disturbance in the financial markets, the disasters of speculation thus thwarting the legitimate hopes and ambitions of industrial enterprise and checking new investment, electric lighting has experienced no setback. The rate of gain over previous periods has apparently been maintained, if indeed it has not been accelerated.

Statistical data are the first that should receive consideration, and fortunately we now have a firm basis upon which we can found our study and analysis of the figures of electric light and power. When I had the honor to present my report last year as Committee on Progress, the United States Census statistics were not available as to the growth and status of the art. They have since been published, and are perhaps now familiar. As special expert for the government in connection with this work, and having an opportunity, therefore, to test the work done, I can speak with praise in regard to the conscientious, intelligent and painstaking manner in which Messrs. S. N. D. North (now director of the Census Office) and W. M. Steuart (now chief statistician for the Department of Manufactures in the Census Office) sought to verify and confirm every statement given out.

FIGURES OF THE INDUSTRY

It is to be borne in mind that the figures quoted are for 1902, but they are the latest available and now for the first time become part of the association's record. These being the first compiled, it is difficult to establish a percentage of annual gain, but it is safe to say that the rate of increase each year is not less than 10 per cent. A great many companies do better than that. At the time of the enumeration there were 3620 central electric stations in operation. The cost of their construction and equipment amounted to $504,740,352. The gross income for the year was reported at $85,700,605, and the total expenses at $68,081,375. These stations furnished employment to 23,330

wage-earners, who received $14,983,112 as wages during the year. The power-plant equipment consisted of 5930 steam engines with 1,379,941 indicated horse-power, and 1390 water-wheels with a stated horse-power of 438,472. The generating plants consisted of 12,484 dynamos of every description with a stated horse-power of 1,624,980. A noteworthy feature in the development of this industry has been the installation of plants operated under the control of municipalities. There were 815 of these plants in operation. The cost of their construction and equipment was reported at $22,020,473. They gave employment to 2467 wage-earners and paid $1,422,341 in wages.

The above figures, however, do not tell the full central-station story, as during the same year there were 252 electric railways doing a central-station business; nor, of course, are any data presented from the 50,000 isolated plants—more or less—that exist all over the country. The current output for the year was estimated and returned at 2,507,051,115 kw-hours, or about 25 per cent of the possible work that the stations could do in 24 hours of daily operation. There were 385,698 arc lamps operated and 18,194,044 incandescents. There were reported 99,102 stationary power motors on the circuits, with a capacity of 619,283 horse-power; and 2379 trolley cars were supplied with current. Of the street railway companies in the lighting field, as shown by the Census report on the street railways, 118 made reports that were kept separate, although 252 such companies generated current for light and power, with a total income from it of $7,703,574. They had 33,863 arcs; 1,442,685 incandescents and 10,049 motors of 35,688 horse-power.

It is interesting to note that all the street railways of the country had just about 1,300,000 horse-power in engine and water-wheel capacity. The lighting plants had just about 1,750,000 horse-power. The output for the street railways was returned at 2,261,484,397 kw-hours for the year, or 6,249,910 per day; so that while the output of the lighting plants was a quarter million kilowatts larger daily, the plants ran fewer hours. This is quite in accordance with observation. The dynamo capacity of the street railways was 1,204,238 horse-power, while the dynamo capacity of the lighting plants was 1,615,480 horse-power. Reducing this to kilowatts, it would appear that the capacity of the railways was in full use nearly eight hours daily, while the

capacity of the lighting plants was in use about six hours daily. The railway figures are a little later than those of the lighting plants, but they all overlap sufficiently to permit this interesting comparison.

CONDITIONS ABROAD

Last year I gave some figures from various countries abroad as a gauge of our own progress, aside from their direct interest. I trust the time will soon come when, either through the work of governmental census bureaus or of kindred bodies, this association may be able to undertake the valuable task of comparing the electric-light statistics of the whole world. Such figures would be at once instructive and stimulating, and not altogether so flattering to our national pride as a superficial examination might indicate.

Perhaps England should receive our first attention, and the figures there are presented in the recent inaugural address of President R. K. Gray, of the British Institution of Electrical Engineers. He pointed out that two-thirds of all the electric lighting in the United Kingdom is in municipal plants and only one-third in the plants of private companies. In fact, if London, the main home of the companies, be excluded from consideration, nearly seven-eighths of the lighting is in the hands of municipalities. In the United States only about five per cent of the lighting is municipal. The average rated capacity of a British station is about 1400 kilowatts, while that of the United States is only 340 kilowatts. The total rated station capacity in Great Britain is, however, given only as 480,000 kilowatts, while in the United States the total in June, 1902, was 1,200,000 kw for less than 4000 plants as compared with less than 400 British. Consequently while the average British station is four times as large as a United States station, the United States lighting is nearly three times as large as the British. A noticeable feature mentioned in the address is that while candle-powers of lamps are less in Britain than with us, so that the standard is the 8-cp lamp, yet the distributing pressures are generally higher, and 200-volt lamps are much more common. In this country the large stations, which began operations upon 110-volt lamps with the three-wire system, have not generally judged it to their advantage to change to 220-volt pressures. Nernst lamps are spoken of as a factor in British electric lighting, and also osmium lamps, which latter

are still curiosities in this country. They are described as having, in 25 and 30-volt pressures, an efficiency of two-thirds candle per watt and as showing but little diminution in light or efficiency after 800 or 1000 hours of burning. Motors are gaining ground in England, and, exclusive of power or transmitting companies, the public supply stations had motors of an aggregate capacity of 55,000 horse-power connected to their mains.

As to Germany, the latest authentic statistics are about a year old, but this is a normal interval. In April, 1903, no fewer than 971 stations were reported. There were 50 plants that had a capacity above 2000 kilowatts. The highest capacity, namely, 26,523 kilowatts, was that of the Moabit station, of Berlin. The total capacity of these 50 stations, situated in 37 cities, was 271,479 kilowatts. The total number of plants reporting was 939 (against 870 in 1902), to which there were connected 5,050,584 (against 4,200,203 in 1902) incandescent lamps of 50 watts, 93,415 (against 84,891 in 1902) arc lamps of 10 amperes, and motors of an aggregate capacity of 218,953 horse-power (against 192,059 horse-power in 1902). There were a number of stations that supplied current, not to a single town, but to a number of towns. For instance, the Bruehl station supplied 66 towns, at a distance of 9 to 12 miles, with current for light and power. The whole industrial district of upper Silesia was supplied from a single plant, while the water-power plant at the Rhine falls supplied 46 towns. In the industrial districts near the Rhine, there were a number of smaller stations that supplied current for power, not merely for factories, but in houses and small shops. For instance, the station of Anrath, near Crefold, supplied current to motors, each of not more than a quarter or a half horse-power, used for silk manufacture in houses. The following figures are taken from the summary of the 939 stations. There were 766 stations with 257,243 kilowatts, using direct current; 45 stations with 30,550 kilowatts, using single or two-phase alternating current; 59 stations with 83,283 kilowatts, using three-phase current; two stations of 970 kilowatts with monocyclic systems, while 67 stations used a mixed system. Of the latter, 55 stations with 102,470 kilowatts used a combined three-phase and direct-current system, while 12 stations with 8041 kilowatts used a combined single-phase and direct-current system. The 939 stations were

situated in 906 cities; 552 stations with 316,235 kilowatts used steam-power, 98 stations with 24,851 kilowatts used water-power, and 61 stations with 6378 kilowatts had gas engines. In one station, with 220 kilowatts, wind-power was utilized; 196 stations with 41,861 kilowatts used both hydraulic and steam-power. Of the 939 stations, 339 had a total capacity up to 100 kilowatts, 422 stations a total capacity between 101 and 500 kilowatts, 90 between 501 and 1000, 39 between 1001 and 2000, 30 between 2001 and 5000 kilowatts, and 19 more than 5000 kilowatts. There were in use 203,758 electricity meters.

It may be pointed out as suggestive, to say the least, that while we used 30,000 kilowatts of storage batteries, the Germans used 87,000 kilowatts; that they had 6378 kilowatts capacity with gas engines, or six times as much as in the United States; and that they had 203,758 service meters compared with our 582,689, although our business is nearly four times as large as theirs. The German plants, like the English, also averaged larger than ours, namely, 420 kilowatts against 340.

A third country to serve as a gauge is Spain, which, backward as some people think it, shows up quite favorably from an electrical standpoint. In recent years, electric light has come into very extensive use, not only in the houses of the more prosperous classes, but quite generally throughout the towns. There were installed 6575 kilowatts in 1880, 12,762 in 1890, 78,475 kilowatts in 1901, and in 1903 about 100,000 kilowatts. This represents five watts per inhabitant. In Germany 438,772 kilowatts were installed in 1902; that is, 7.5 watts per inhabitant. This compares with about 12 watts per head in England in 1902-3 and 16 watts per head in the United States in 1902. There are about 1000 central stations in Spain, and the development of electric lighting has been especially rapid in Madrid and Barcelona. In the larger cities the three-wire, direct-current system is mainly used with 220 volts between the outers, some plants using, however, alternating current. In Madrid, 16,600 kilowatts of machines and 17,700 kilowatts of storage batteries were installed, so that 66 watts were installed per inhabitant (against 48 watts per inhabitant in Berlin). Since 1890 the development of water-power has steadily increased, alternating current being mostly generated and transmitted to a number of different towns. The profits of the electric stations are high, a dividend of 30 or 35

per cent being nothing unusual. The methods of house wiring are very crude. Some high-tension transmission plants have recently been erected. The financial returns are to be envied.

OTHER FOREIGN COMPARISONS

Anticipating to some extent other portions of this report, note may be made here of the interesting observations on European conditions presented last September before the Association of Edison Illuminating Companies by Mr. Arthur Williams. In regard to London, he remarked that as to arc lighting the prices paid by the municipality vary from $110 to $150 annually for an arc lamp of about the same size as our lamp rated at 2000-cp. The practice is to place the lamps much nearer together, in many instances averaging not more than 100 feet apart. The city furnishes the posts and shades; the companies provide all else, giving the lamps the usual attention. Inclosed-arc lamps have made very little headway; and for the most part they have not given satisfaction to the users. The reason the English engineers adhere so devotedly to the open-arc lamps is that in London and other English and European cities the price of labor and carbons is low, while the cost of current is high—the reverse being true in our American cities. There are 36 companies or vestries in London operating electric lighting plants. The aggregate of the installations was hardly more than 5000 horsepower, and the arc lamps were something less than that number. It appears that 13 of the companies or vestries use Wright demand meters, not exclusively, but in conjunction with their rates. The companies using these meters control about 45 per cent of the total installation.

A novel kind of rate was that adopted by the St. James and Pall Mall Company, in London, for long-hour, usually "hidden" lighting. By hidden is meant the lighting of hotel, apartment-house and club cellars, kitchens and servants' quarters, shops below the sidewalk level, basements and the public-comfort conveniences, which the city of London has liberally provided at the large intersections. The retail rates of this company were 12 cents a kw-hour for the first 4000 kw-hours of annual use and eight cents for all over, with a discount of eight per cent on all bills paid quickly—say within 30 days. To meet the competition of gas in the places mentioned, the company adopted a new

schedule, under which all "below street level" lighting is supplied at exactly half the usual rates. That is to say, the first 4000 kw-hours are charged for at six cents instead of 12 cents, and the remainder at four cents instead of eight cents—and the additional discount of eight per cent is also allowed. If the consumer's premises are half above and half below the street level, he is given the benefit of a liberal interpretation of the schedule, and charged altogether at the low rates. Separate meters are provided where necessary to separate other parts of the premises supplied at the higher rates. English, or perhaps London, views regarding credit are interesting. Payment within 30 days is considered cash; nine months are not unusual. It may be of interest to know that one company charged 12 cents a kw-hour for service at 100 volts and 10 cents where taken at 200 volts.

In Paris, Mr. Williams found that, as in London, the use of arc lamps for street lighting had increased, in the last two years, the greatest service being in the centre of the city. Open lamps are used, again because of the low cost of carbons and labor and the high cost of current. The lamps are spaced apart an average not exceeding 100 feet; in some places the distances are much less. There seems to be no desire on the part of the city officials to utilize the private-window lighting for the illumination of the thoroughfares; and this is well, for there is little, if any, display lighting of that order that is worth mentioning. The companies supplying electric current are limited in their franchise to a maximum price equalling 30 cents a kw-hour, but there is no limitation upon the extent to which this price may be reduced. The average price obtained is about 22 cents a kw-hour. Companies making electric current inside the city's walls pay a tax of five per cent on their gross income, while those that generate outside the walls, thus avoiding the octroi duty paid upon coal brought within the fortifications, pay one per cent additional, or six per cent. The cost of municipal arc lighting, where supplied by private companies, is at the rate of $240 annually, but the annual expenditure is in many cases lessened through the disconnection of the lamps at midnight or shortly thereafter. As the companies are taxed upon their gross income, this figure is reduced five per cent or six per cent, as the case may be, so that the net cost is not far from $225 a lamp annually. At the end of 1901 the five private companies and the municipal

plant of Paris had 68,267 kilowatts of installation, equalling 1,365,340 sixteen-candle equivalents. The capacity of all the stations was 38,000 kilowatts, or 56 per cent of the installations. Twenty-seven million three hundred and twenty-two thousand kw-hours were sold, the consumption averaging about 400 hours per unit of installation.

RATIO OF CURRENT COST AND CONSTRUCTION

American private companies will note with interest the rates quoted above for electric lighting and would be glad to secure such prices for their arcs. One of the best things done by this association last year was to publish a bulletin of American rates for light and power. I may quote here some of the data for reference, and for comparison. Berlin, for example, has this year current at 10 cents per unit for lighting and for power purposes down to a minimum of 3.5 cents. In this country a most conspicuous feature is the tendency to favor the consumer by lower prices. The old basis of 20 cents per unit with small discounts, or approximately one cent per lamp-hour, is now seldom maintained, and when used at all is generally modified by discounts for prompt payment large enough to form a substantial reduction. Common prices are 15, 17 and 18 cents per unit, with liberal discounts. Many plants in the regions of cheap coal have come to even lower prices, as have water-power plants generally, and the number of plants charging as low as 10 cents per unit is surprising. For power service, 10 cents with large discounts is rarely exceeded, while many plants sell at five, six and eight cents, with ample discounts to the larger consumers. The lowest figure for power noted is one cent per unit for consumers taking 300 horse-power or more, but sliding discounts bringing the price down to two or three cents per unit are common in case of water-power plants or those in regions of cheap fuel.

Mr. W. F. White, a well-known central-station manager, in a recent comment said that "The field for the sale of electrical energy is comparatively unexploited. Its sale for general power purposes has only begun. In not a single large city of the United States have the possibilities of the industrial power business been fully developed, much less exhausted. In many of our best cities to-day the gross receipts from the sale of electrical energy for all purposes do not exceed $1.00 or $1.50 or $2.00 per capita per

annum. Such volumes of business can be multiplied three, four or five fold." This is undeniably true, and is as significant for the manufacturer of apparatus as for the purveyor of current. So far as I am acquainted with central-station work in our large cities, there is not a company that is free from anxiety as to how each summer it shall provide plant enough to carry the peak of its load the coming Christmas. As to steady consumption, every company has its own yard-stick data. A recent analysis of the output of a company operating 10 plants showed that with 4904 customers, and 214,934 lights connected, there was an average current used of 27.28 kw-hours per 16-cp lamp.

THE NERNST LAMP

During the last year the Nernst lamp appears to have made steady progress in a field that was already pretty well occupied by competitors. While, of course, there have been some minor improvements made in the mechanical details of the lamp tending toward a simpler and more rugged construction, the commercial success attained may be attributed largely to the fact that the local lighting interests of the country are coming gradually to appreciate the inherent advantages that the lamp undeniably has. In its earlier history or stages, the lamp had to make its way on its merits in a preempted domain, and that it has marked out its own sphere of occupancy repeats once again the record of every new invention of real utility. It is worthy of note that since I reported last, the Nernst Lamp Company in this country, desiring to establish a closer relationship between the manufacturer and user and in a measure control the operating conditions, has instituted the policy of utilizing the central station as the medium for effecting the sale of its product. This policy embodied in a "central-station contract" is of interest and is in effect in St. Louis; Detroit; Appleton, Wis.; Racine, Wis.; Milwaukee; St. Paul; Denver; Madison, Wis.; San Antonio, Tex.; Long Branch, N. J.; Lincoln, Neb.; Harrisburg, Pa.; Durham, N. C.; Winston-Salem, N. C.; Waverly, N. Y.; Sayre, Pa.; Liberty, N. Y.; Reidsville, N. C.; Hoopeston, Ill.; Sycamore, Ill.; Quincy, Ill.; Alliance, Neb.; Sparta, Wis.; Hartford, Conn.; Unionville, Conn.; Sheboygan, Wis.; Lapeer, Mich.; Raleigh, N. C. As illustrative of its vogue, note may be made of the fact that the Nernst lamp is to be used for lighting the entire fine arts exhibit at the St. Louis Exposition.

So much for the strictly commercial aspects of this new illuminant in this country. Abroad, the lamp seems to have made considerable headway, and the direct-current form to be used as well as the alternating-current style still used exclusively here. It is stated that those in use in Buckingham Palace, a royal residence in London, have proved quite satisfactory, reducing the current consumption by about 50 per cent according to a paper read before the Municipal Electrical Association of England. With reference to the experience of the electrical engineer at Gravesend, England, the life of such lamps was also quoted. He installed 48 Nernst lamps of 0.5 ampere in place of incandescent gas burners, and the average life at the end of three months was 960 hours. The 960 hours do not represent the true life, as at the expiration of the three months there were 48 burners alive. From a report of another engineer, who installed three sets of six lamps each, it appears that the average life of one set was 836 hours, of another 575 hours, and of the third 652 hours.

At the meeting of the Iowa Electrical Association in April of this year, experiences with Nernst lamps were reported by several members. Mr. Gardner, of Mount Vernon, Iowa, reported very satisfactory results from one year of operation. The quality of light made it a good lamp in drygoods stores, and his customers liked it, both on account of the quality and the amount of light obtained for the money. The lamp required more attention than incandescent lamps. Mr. Green reported that his company was supplying current heating 500 and 600 glowers. The maintenance of lamps was about .6 cent per kw-hour supplied to the lamp. Mr. Burt stated that in a Catholic church three six-glower lamps had been installed with such good results that delegations from other Catholic churches in the state had come to inspect the lighting. He had found the Nernst lamp a good thing with which to compete with the gas-arc, upon which the repairs were by no means small. His company, which owns a gas plant, charged $1.00 per month maintenance on one Humphrey gas-arc installed for a customer, and 50 cents for each additional arc. The greatest difficulty experienced was the burning out of the heater, usually due to neglect on the part of a customer to turn off the lamp when the glowers were burned out. Mr. Green stated that he was installing three-glower Nernst lamps to do the same work as four-burner Humphrey gas-arcs.

THE OSMIUM LAMP

A great many inquiries have reached me during the year as to the osmium-filament lamp and its availability. So far as I know, none are in regular use in this country, but they are obtainable and in service abroad. The subject is certainly an interesting one, and I have collated a little data. As to the manufacture of the filaments, it has been found possible to produce suitable osmium wires by bringing the osmium in a finely-divided state, mixed with a carrier or binder, into the form of a wire. The wire thus formed is treated in the electric furnace by heating it by means of the current to a high temperature, above that of the vaporization point of platinum. The binding material is thereby destroyed and the individual osmium particles are welded together. The heating of the osmium wire must be carried only to a point at which it still remains finely porous, as dense wires are liable to break in the lamp. The manufacture of a filament consisting of an osmium-platinum alloy is carried out by heating a thin platinum wire by the current in a reducing atmosphere, which must contain hydrocarbons, a considerable amount of water vapor and vapors of perosmic acid. Metallic osmium will separate on the platinum wire, which is then heated above the vaporization point of the platinum. The residual filament is an elastic tube, consisting mainly of osmium, but still containing some platinum. The manufacture of osmium-carbon filaments is also feasible, and filaments including a mixture of thorium or zirconium oxide. In a test made by the German Reichsanstalt of 38-volt osmium lamps during 600 hours, it was found that the consumption of current of the 30 and 35-cp lamps was 1.28 amperes, so that the consumption of power is 1.43 to 1.58 watts per candle of average illumination perpendicular to the axis of the lamp. A considerable decrease of the candle-power during the 600 hours was not observed. Other tests were made by Wedding, who found that the osmium lamp when suspended vertically consumed 1.4 watts per candle against 2.5 to 3.5 watts with the carbon-filament lamp. The absolute life of the lamp is far beyond 1000 hours. Although one lamp was destroyed after 520 hours, the others which were tested had an absolute life of more than 3320 hours. The higher the candle-power, the longer the absolute life. The "net" life of a lamp is the time in which the candle-power is reduced to 20 per cent of its original value; none

of the tested lamps decreased its candle-power to such a degree before the filament was destroyed. This means in practice a considerable advantage over carbon-filament lamps. While the latter lose candle-power on account of the blackening of the globe, the osmium lamps remain clear and decrease in candle-power much more slowly. An auxiliary apparatus for introducing the osmium lamp has been placed on the market under the name of "divisor." This is a device for dividing the voltage into several equal parts, and is to be used where the lamps are not to be worked in series, but independently of each other. It is a transformer with a single winding, divided, for instance, in three equal parts. When its terminals are connected to a voltage of the network equal to 120 volts, this voltage is divided into 3 x 40 volts. This enables one to supply three circuits of osmium lamps independently of one another. The advantages of this device over an ordinary transformer are higher efficiency and smaller cost. The manufacturer is making two types of these devices, one for 3 x 2 and one for 3 x 10 lamps.

The range of voltages for which the lamps may be used has recently been increased, and lamps for 55 volts are now supplied by the Austrian Gasgluehlicht and Elek. Gesellschaft of Vienna. From a report of Wedding it appears that two groups, each consisting of six lamps, of 37 volts, were tested in series across 220-volt supply mains. In one of the groups, for the first 3132 hours, the average life of the six lamps was 2853 hours, and the average candle-power fell from 30.1 to 23.7, the mean consumption in watts per candle-power rising from 1.46 to 1.78. After 520 hours the first lamp collapsed, and after 3724 and 3940 hours, respectively, two others gave way, the remaining three still burning after 3973 hours. For the second group, which consisted of six 25-cp lamps, the average life was 1479 hours, the candle-power dropping in 2198 hours from 25.1 to 19.9 and the energy consumption increasing from 1.37 to 1.75 watts per candle-power. The filament of the lamps is made up of two loops, which are held apart by insulating stays or anchors attached to the interior of the glass bulb. The use of the lamp in train lighting is also to be noted, namely, on the Marienburg-Mlawka Railroad in Germany, in place of carbon-filament lamps. The current is derived from storage batteries carried on the train. As the incandescent carbon lamps formerly used were

not very durable and showed a diminution of their lighting power toward the end of their life, osmium lamps were substituted at the beginning of August, 1902. They gave 10 candle-power at 16 volts, and the calculated energy consumption was 1.5 watts per candle-power. The storage batteries then required recharging after 72 hours, whereas with the old lamps they had to be recharged after 32 hours, the final voltage being in both cases the same. After burning 750 hours, no diminution in the light could be observed in the osmium lamps, the bulbs of which kept perfectly clear while those of the carbon lamps had blackened. The vibration of the trains does not affect the lamps. For the ordinary incandescent lamp, with an average life of from 300 to 400 hours, 22.5 cents were paid; for the osmium lamp, with an average life of 1000 hours, the cost, it is stated, was $1.19; the cost for depreciation was, therefore, 0.056 cent for the old lamp and 1.119 cents for the osmium lamp.

It would appear that the European commercial lamps are sold for 16 volts at 10 and 16 candles, 25 to 30 volts at 25 candles, 27.5 volts at 16 and 25 candles, 32 to 44 volts at 25 to 32 candles. The supply of osmium is small, and the price of the lamp is, therefore, high, namely, $1.25; 19 cents are given back if the burned-out but unopened lamp is returned within 18 months. The filament of such a lamp can be treated and used again.

SOME NEWER LAMPS

One of the promised novelties is a new direct-current arc lamp in the hands of the General Electric Company, about which not many details have yet been given out. It is known as the "Magnetite" lamp. The negative electrode in the lamp is a stick of magnetite, while the positive electrode is a copper block, which is practically without wear. The stick of magnetite is five-eighths inch in diameter and eight inches in length, and burns for 150 hours without the necessity of an inner globe, as in the inclosed arc. The production of light for 300 watts is put down as equal to that of the ordinary arc at 450 watts. The lamp would appear to have advantages for street work, but is apparently not adapted for indoor service, on account of the smoky deposit.

In connection with this lamp Mr. Charles B. Steinmetz, who has been giving special attention to the subject, says: "In the case of the magnetite arc lamp only the negative or lower elec-

trode consists of magnetite, and is consumed. The positive terminal is not replaced, but is a copper segment, which constitutes a permanent part of the lamp. The metals of the iron group yield a brilliant arc flame of very high efficiency and white color. To give a long life the metals which are combustible are not well suited, but a stable oxide of these metals must be used; that is, a compound which can not burn any more. Amongst the conducting oxides, magnetite fulfills best the requirements of a carrier of the arc flame, since it is well conducting, stable at all temperatures, very plentiful in nature, and gives a white arc of high efficiency. Pure magnetite, however, is not quite satisfactory, since its efficiency is not very high, hardly twice as high as that of the ordinary carbon arc; and the arc tends to flicker and the rate of consumption of the electrode is rather high; as high as one-eighth inch per hour. This, while very much lower than the rate of consumption of flame carbons, of one inch to two inches per hour, would still give only 50 to 60 hours' life with the standard size of electrode adopted for the magnetite arc lamp, of eight inches length. Therefore, with the magnetite as carrier of the arc flame are incorporated other substances in small quantities as arc-steadying compounds—titanium compounds for increasing the efficiency, etc.

"In the manufacture of these magnetite arc electrodes, by partially reducing the material to metal, a greater density is produced and so a greater amount of material with the same size of electrode, which gives a longer life. Such partial reduction, however, has the disadvantage that when not carried far enough it leaves the electrode porous and of relatively short life, while when carried too far, the light tends to unsteadiness, turns faint and blue whenever the arc strikes metal, and in this case scintillating sparks are thrown off, which may crack the outer lamp globe. A much better method of producing electrodes was found by not reducing the material, but adding a restrainer; that is, a substance which added to the electrode material in small quantities reduces the rate of consumption. Hereby, without any loss of efficiency, rates of consumption of 20 to 30 hours per inch are produced, which give a life of 150 to 200 hours for the eight-inch electrode. With very little sacrifice of efficiency a life of 500 to 600 hours is produced, and such an electrode has about the same life as an incandescent lamp; that is, the arc

lamp requires trimming about as often as an incandescent lamp requires renewal. This latter feature, however, while obviously valuable in cases where trimming is difficult, as with lamps in inaccessible places or during protracted strikes, etc., for general illumination is hardly needed, since it would in street lighting give a life of two months; and a street lamp should be looked after oftener than this.

"A simple and satisfactory form is an electrode in which the material is compressed as impalpable powder in a thin iron tube, which is then sealed over by the arc. In the carbon arc lamp the light comes from the incandescent crater of the positive carbon and not from the arc flame. Hence, the arc lengths should be made as short as possible without obstructing the escape of light from the crater. In the magnetite arc, however, no light issues from the terminals, but all the light comes from the arc flame, and an arc length from three-fourths to one and one-eighth inches is, therefore, most efficient. Furthermore, to give a constant volume of light the arc lengths should be constant. This leads to a feeding mechanism differing from the "floating system" of the carbon arc lamp and much simpler; that is, a feeding device maintaining constant arc length. The operation of the magnetite arc lamp is, therefore, as follows: When the power is put on the lamp, the arc is struck by separating the electrodes to a definite distance, say seven-eighths inch, and then the electrodes are locked in this position and remain fixed until after some hours or so, by the consumption of the negative electrode, the arc length and thereby the arc voltage has increased sufficiently to operate the feeding mechanism which resets the arc to its original length."

Details were made public last year in France of tests of a new type of arc lamp, like the Bremer, and of the method elaborated by Blondel of arranging and treating the carbons. The carbons are constructed in several zones or layers, and the mineral admixtures, which are fusible salts chosen for their luminous capacity, are incorporated in considerable proportions with the carbon in the inner zones. The outer zone is formed of pure carbon, and it is stated that it protects the carbons against lateral combustion, and also gives them the necessary conductivity. The arrangement of the electrodes is such that a very highly mineralized

carbon is placed below another less mineralized, thus producing the result that the arc between the two is constantly situated below, and in the axis of a disc of refractory material. The latter disc serves as reflector and also to prevent the arc from climbing up on the upper electrode. The table shows that a lamp of 3.3 amperes gives 1.5 times more light than a 10-ampere lamp of the old style and 6.5 times more than a 3.3-ampere old-style lamp.

At a recent meeting of the Vienna, Austria, Electrical Society there was exhibited a new incandescent lamp patented by Just, which is claimed to represent an exceedingly important progress in electric lighting, since the lamp is to use only half the current per candle required by the carbon-filament lamp. Such lamps have been built for 30 candles and 110 volts to two watts per candle. Two such lamps of 30 candles were exhibited by the speaker. The commercial manufacture of the new lamp, "the filaments of which are treated with an addition of boronnitride," is said to be neither more difficult nor more expensive than that of carbon-filament incandescent lamps. To a question whether lamps for 16 candles and 110 volts have been made, it was said that the manufacturers have not yet succeeded in building this normal type, but they hope to be able to do so in the near future. The manufacture of 16-candle lamps for voltage up to 50 volts is, however, already possible.

THE INCANDESCENT-LAMP INDUSTRY

It is only fitting that this report should mention the commemoration this year of the twenty-fifth anniversary of incandescent lighting in America, and the foundation of the Edison medal, to celebrate the event, in the American Institute of Electrical Engineers. This medal is to be awarded annually to the student producing the best thesis or record of original search, in our colleges, and a fund of over $7000 was readily raised from among Mr. Edison's associates, friends and admirers. The banquet in New York last February to celebrate the occasion was one of the most notable electrical events of the kind. In speaking of the growth of the industry, Mr. Edison said recently that the production in this country of incandescent lamps had reached a total of about 250,000,000, or 10,000,000 annually since 1879. The present American consumption, it may be added, is about

45,000,000, and the productive capacity of existing factories is about 65,000,000. As to the technical and commercial progress in the period, Mr. John W. Howell says: "The exhaustion of lamps by mercury pumps required from four to six hours in 1881. Improvements in pumps and methods reduced this to one-half hour in 1895. Since then, by simple piston pump and 'chemical exhaust,' a much better result is produced in one minute. The cost of exhausting a lamp at the end of 1882 was considerably greater than the total cost of a lamp at the present time. All the glass-working operations have been changed from hand work by 'glass blowers' to machine work by unskilled labor. The labor cost of the principal glass operations is now a little more than 10 per cent of the cost in 1882. Until 1894, Edison filaments were made from a bamboo piece passing through eight separate hand operations. Now squirted cellulose is used. In this department we now employ 83 operators. If we should go back to bamboo fibre we should require over 2150 operators for the same production. The cost of photometric measurements is now nine per cent of the cost in 1882, with a great gain in accuracy. The lamp in 1880 contained at least 30 times as much platinum as the lamp of the present day. The amount and cost of glass and other materials used have also been greatly reduced. The lamps made at Menlo Park for the steamship *Columbia* in 1880 consumed about 100 watts for 16 candles. To-day the standard 16-cp lamp consumes 50 watts. The useful life of a 50-watt lamp to-day is undoubtedly longer than was the useful life of the 100-watt lamps of 1880, and while we have no data for a correct comparison showing the improvement that has taken place, we can get a good idea of it from the fact that the estimated useful life of a 100-watt, 16-cp lamp made to-day is over 10,000 hours, which is about as many times the probable useful life of the 1880 lamp as the number of elapsed years."

COMPARISONS WITH GAS

A report was made recently of the public lighting done for the city of Westminster, London, England. It includes tests of the various illuminants there used, both as to their actual candle-power and their cost, and embraces arc lamps and various forms of gas burners, ranging from mantle burners worked under high pressure down to common flat-flame burners of the type

generally discarded in this country. The report containing the data is the fifth quarterly report on the subject, so that the public lighting may fairly be said to be under systematic test. The costs are reduced to a candle-power-year basis and range from 32.6 cents per candle-year for the flat-flame gas burners down to 18.8 cents for the best arcs and 18.24 cents for the intensive mantle burners. Perhaps the most striking fact brought out is the relatively uneconomical result attained by the ordinary mantle burners. The cost per candle-year for these lamps was just about 34 cents, or, roughly, 50 per cent more than the average cost with arc lamps. This increase seems to be mainly due to the high cost of maintenance, which amounted to between \$5.00 and \$6.00 per year for each burner.

From Germany comes a little controversial data over an official report of Seggel and Eversbusch concerning the best lighting system for the Bavarian public schools and in favor of incandescent gas light. To counteract this, the Schuckert company presented another report by Lehmann-Richter, giving the results of comparative tests with two arc lamps or 14 gas incandescent lamps in a school-room. The illumination was good in both cases and sufficiently uniform. The electric light did not deteriorate the air nor increase the temperature considerably. With gas incandescent light the temperature at the height of the pupil's eye was increased in three hours about six degrees, while the carbonic-acid contents of the air was increased five times. This is thought to be more than permissible for sanitary reasons. The cost of operation of the Welsbach lights is smaller than that of the arc light in the beginning, but after a short use the cost of operation of the Welsbach mantles becomes as high as that of the arc light.

According to the United States Census Office figures, the electric-lighting industry has already caught up with that of artificial gas, and there is no sign of any slackening of pace so far as electricity is concerned. As to the status of gas, some suggestive data compiled by Mr. Alton D. Adams, as to Boston, will be of interest, especially as the city where we meet has been so prominent as a field of water-gas activity. Discussing figures that need not be reproduced here, he says: "Water gas, starting with only 12 per cent of the total volume of gas sold in Boston in 1890, increased rapidly to 90 per cent of the entire volume in

1894. From the fiscal year last named to that of 1899, inclusive, the percentage of the water gas made to the total product sold was never below 90, and in two instances stood at 97. During these five years water gas substantially displaced coal gas in the local field, but not in one of them did its brilliant illuminating power or alleged low cost of manufacture check the expansion of electrical supply. In only two years out of the five was the total volume of gas sales materially raised, and then the increase was due to free gifts of gas stoves. These stoves appear to have raised the annual consumption of gas about 75,999,999 feet, which would leave the volume of gas yearly burned for illumination just about stationary from 1890 to 1899, inclusive. Now, a stationary consumption of gas for illumination in the face of an increasing population means an actual decline in the use of gas *per capita* for that purpose. It is highly probable that this is just the situation which the Boston gas interests have to face. For the decade from 1890 to 1900 the increase of population at Boston was 25 per cent. If the fifty-odd thousand gas stoves now used in the city are doing much baking, it seems hardly probable that illumination by gas has kept pace with the population. Consideration of the years 1900 and 1901 has been reserved until this point, because they present several new and interesting conditions in the gas and electric field. For the first time during the 11 years under consideration, gas sales show a substantial gain without the aid of an artificial stimulus, like gifts of gas stoves. This gain in the volume of gas sold for 1901 was 12 per cent over the volume for 1899. Strange to tell, however, while the total volume of gas was going up, that of water gas, the cheap, brilliant illuminator, went rapidly down. From 96 per cent of the total volume of gas sold in 1890, water gas fell to only 37 per cent of the like volume for 1901." Incidentally, it may be mentioned that the gain of electricity in the period named was 23 per cent as compared with the 12 per cent for gas. It may also be added that in some other figures Mr. Adams has shown for Massachusetts an increase in central-station dynamo capacity from 1888 to 1900 of 6842 kilowatts to 68,941 kilowatts, a tenfold increase, with 15.8 times increase in the connected capacity of lamps and motors.

At the last meeting of the Ohio Gas Light Association, the subject of high-pressure gas in street lighting was discussed

by Mr. J. J. Knight, who said: "All things considered, the most efficient, satisfactory, and therefore most generally adopted street-lighting system in use to-day is probably that furnished by the use of the so-called 2000-cp open electric arc lamps, hung from 20 to 30 feet from the ground and in the centre of the street intersections the long way of the block and alternate intersections the short way of the block. The lamps so placed are usually about 500 feet apart, except in what may be called the police districts, where they are placed somewhat closer. A better system, except for the matter of expense, would be the use of the inclosed electric arc lamps placed, say, 200 feet apart on alternating sides of the street, hung from 12 to 15 feet high. There may be earnest gas men who will not agree with these statements, and who believe that single-mantle gas lamps of the modern type placed at short intervals are more satisfactory. It is possible that such would be the case if they were frequent enough, were well maintained, and were not subject to disability and damage from frost, wind, bugs, etc., and the cost of installation, operation and maintenance did not exceed the cost of electricity. I am quite sure that, as a general proposition, the electric light is more favorably regarded by the average citizen not interested in gas, and it is probably not wise to let our enthusiasm lead us astray in this matter." All the same, Mr. Knight plans to ask his home city of Kalamazoo, Mich., to let him try some high-pressure gas lighting with three-mantle lamps. It may be noted that at Kalamazoo the city council has proposed to abandon its municipal electric-light plant and contract with a private company for street service. In commenting on the Knight proposition, our own past-president, Mr. Henry L. Doherty, said in the discussion: "I think you will have a greater competition from other forms of electric street lighting than from the inclosed-arc lamps, and that we ought to keep in mind the fact that we have to do something better than to beat the inclosed-arc lamp. The series open-arc lamp, were it to be operated upside down, with a properly designed reflector, would, to my mind, undoubtedly give very much better results than could be secured by the inclosed-arc lamps. I think, in spite of the fact that the Nernst lamp does not give as high an efficiency as is ordinarily claimed by the manufacturers of the lamp when considered as a source of light in every direction

from the lamp, it can be used in smaller units, and as the light decreases in reverse ratio to the square of the distance, the minimum illumination is, perhaps, greater for the same consumption of watts than any form of arc lighting, even though the total flux of light is less. The Cooper Hewitt mercury vapor lamp, I believe, is the most promising lamp for street lighting at present. But if I were competing for a street-lighting system myself, I think I should prefer to use some system of smaller units, either the Nernst lamp or something of that sort, in preference to the inclosed-arc lamps, and I should be much inclined to the Cooper Hewitt lamp for street-lighting purposes. We have to do something better than compete with the inclosed-arc lamp, and while we are able to secure a great deal of street lighting with the ordinary incandescent gas lamp, we may have a harder time to do that in the future, unless we increase the efficiency of the incandescent gas lamp."

MERCURY VAPOR LAMPS

This brings us fitly to the subject of the mercury vapor lamps, in regard to which considerable data are already in print. Since our last report, the Cooper Hewitt Electric Company has done a good deal of work in introducing this novelty. In fact, in New York city it has ceased to be a novelty, as the lamps are to be seen in many store windows, and are in use in many interiors. Mr. D. P. Cameron, of this company, informs me that for illumination purposes—aside from photography, etc.—they have two types of lamps. One is a 700-cp consuming 3.5 amperes on 110 volts, and the other a 300-cp running two in series, and consuming 3.5 amperes on 110 volts. The present life averages about 1200 hours, and on that basis the cost of maintenance averages about one-quarter of the bills for current. These lamps have gone rather on central-station circuits than upon those of isolated plants. As another example of American electrical export trade, it may be mentioned that these lamps have been shipped to Sweden, Germany, England, Scotland, Mexico, China and Japan.

An interesting modification of the mercury vapor lamp has been brought out in England, by Bastian and Salisbury. Its efficiency is lower than that of the outright Cooper Hewitt lamp, but it has a convenient form, and the color is appreciably improved.

The engraving herewith shows the lamp in its normal position. *E* is a spun-copper bell-shaped cover which protects the internal mechanism from wet and provides a means for suspending the lamp and fixing the tubes and other devices. *G* is an ordinary glass globe. As shown in the illustration, the lamp is not at work, and the mercury in the tube *T* connects the two wires sealed into the glass. Fixed to one end of the glass tube is an iron plunger *C*, which acts as a core to the electro-magnet *M*. The resistance *R*, the electro-magnet *M*, the carbon-filament lamp *L*, and the mercury in the tube *T*, are all connected in series. On closing the switch, the core *C* is drawn up by the electro-mag-

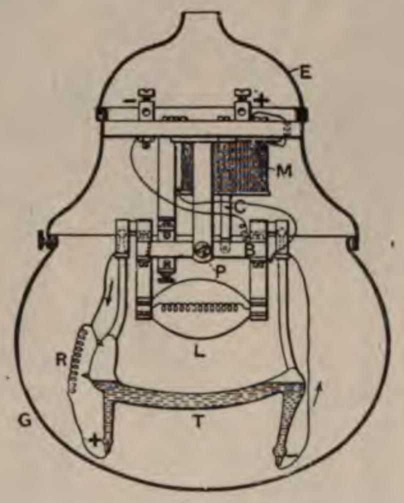

Fig. 1

nets; *T* being pivoted at *P* and the continuity of the mercury being broken, an arc is formed. The tilting of the tube is thus effected automatically. The pressure of the mercury vapor set up by the arc then forces the mercury up into the left-hand bulb and thus cuts out the auxiliary resistance *R*. All these operations occupy but the fraction of a second. The carbon-filament lamp *L*, just above the mercury tube, is added for the purpose of overcoming the absence of red rays, and this lamp is, therefore, underrun so as to make its radiation rich in the required red rays. An efficiency of 2.5 candle-power per watt is claimed when the carbon auxiliary is not used and of 1 to 1.5 candle-power per watt when the latter

FIG. 2.—ILLUMINATION OF AUTOMOBILE BATTERY ROOM WITH MERCURY VAPOR LAMPS, NEW YORK CITY.

is used. Each lamp requires from 40 to 60 volts and 0.65 ampere, the candle-power being 80. Lamps have been run both continuously and intermittently for over 1500 hours, and the inventors believe that the average life will be about 3000 hours. The resistence of the carbon filament in series decreases the voltage across the terminals of the mercury tube and consequently the length of this tube. Friends of mine from England not interested in the lamp speak very favorably of its light.

As an evidence of what can be done with the mercury vapor vacuum tube a view is here presented of the battery room of the New York Transportation Company, which operates hundreds of electric hansoms and cabs on Manhattan Island. This large room, 300 feet long by 42 feet wide and 26 feet high, has been a most difficult place to light on account of its darkness, the blackness of the cells, and the all-pervading presence of sulphuric acid fumes. For this reason the 14 five-ampere arc lamps which were at one time employed were replaced some months ago by 10 mercury vapor lamps of three amperes each. In this manner the current consumption has been cut in two, the general economy of the system appears to have been greatly increased, and the illumination is remarkably greater than it was before. The Cooper Hewitt lamps are run about 24 hours in a day and need very little attention.

Under the head of vacuum-tube lighting, reference must be made also to the work of Mr. D. McF. Moore, who has continued to apply himself persistently to perfecting applications in this field. His tubes give a very pure white light, and have been adopted for photographic purposes, in the form of movable skylights, the tube being doubled up into a large, flat, window-like box that can be shifted around at will in the photographic studio. In one such window the tube has a length of 43 feet, and is credited with a life of at least 1000 hours, operating on a basis of five candle-power per foot, or about 200 candle-power total (see page 27). Similar apparatus has been devised by Mr. Moore for photographic print, and a good length of tube can also be seen nightly at the entrance of one of the buildings on upper Fifth avenue, New York city.

SPECIAL REFLECTOR INCANDESCENT LAMPS

Some time ago, reflector incandescent lamps were brought out, with the upper half of the bulb silvered for reflector pur-

poses. These do not appear to have remained permanently in the art, but they have proved to be the first step in a most interesting evolution, and to-day in the United States several concerns are introducing special forms of incandescent lamp com-

FIG. 3

bined with a shade, so as to give very efficient and uniformly diffused illumination beneath the lamp. One can never tell whether a novelty is just a fad or something that has come to stay, but these reflector lamps have certainly made a decided hit.

Possibly the Nernst lamp has helped to stir up improvement in this direction.

A now familiar type of this lamp is that designed by the General Electric Company and there are several others. It is made with a ground-glass, spherical, tipless bulb about five inches in diameter. The aluminum reflector covers the upper half of the bulb, fitting closely thereto, and the junction of the lamp and socket is concealed by a metal collar. The lamp as first designed was made in a unit of 50 candle-power consuming from 100 to 120 watts. The introduction of the lamp, however, led to a demand for a smaller unit consuming about the same current as the ordinary 16-cp lamp, and accordingly a unit just half the candle-power and watts consumption of the first one designed has been placed on the market during the year, and has proven even more popular than its predecessor. It is made in a smaller diameter bulb 3.75 inches in diameter and is very serviceable for residence lighting, for desk and table illumination. Where the number of outlets permit, it secures a greater uniformity of illumination by distributed lighting with a large number of units than is possible for the same power consumption with the 50-cp size of lamp.

A year's service of the lamps has introduced a number of improvements, chief among which has been the adoption of a new form of glass reflector in place of the metal reflector. It has the upper surface covered with a fluting of 90-degree prisms. They form a surface which, on the well-known principles of reflection, secures a maximum effect in the downward distribution of light. The shade is translucent and appears radiant with light when the lamp is lighted, thus greatly increasing the attractiveness and artistic appearance of the lamp. The advantage claimed for the shade is that it does not rest upon the lamp, but is suspended from the socket, and is made in such a form as to allow ventilation of the lamp, thus dispersing the heat, increasing the life and maintaining the brilliancy. The present lamp with its new shade, therefore, gives considerably longer life and better sustained candle-power, equaling and surpassing that of the ordinary 16-cp, 3.1-watt lamp. In introducing this lamp the company has made its first cost low in order to provide an inexpensive unit, and many central stations have placed the lamp on the free-renewal list. They have been

able to do this because the renewal of the lamp, when figured on the kw-hour basis, is no greater than that of the ordinary lamp in 8-cp or 10-cp frosted bulb—a type of lamp that is regularly supplied free by the majority of central stations.

The use of lamps of the Meridian type greatly simplifies the problems of illumination, as each lamp gives an almost perfectly uniform distribution of light beneath, and this uniform illumination extends over an area having a diameter equal to the height of the lamp above it. This fact provides a simple rule by which the lamps can be properly placed for the uniform illumination of any interior. Another advantage secured is dispensing with the use of ordinary fixtures. The lamp, except with high pitches, can be placed on the ceilings or suspended a few feet therefrom, and in being distributed over the ceiling secures much more satisfactory and uniform illumination than is possible where the lamps are bunched on a fixture in the centre of the room. Several lighting companies are using these lamps in clusters as successful competitors of the so-called gas-arcs. Altogether, the introduction and use of these lamps has tended to improve greatly the art of lighting and to assist greatly central-station lighting companies in their competition with other forms of illumination. An instance mentioned to me recently is that of a railway station on the Jersey Central Railroad. The waiting-room is about 20 x 40 feet. The sole illumination is two five-inch Meridian lamps at the centre of the room and two standard 16-cp lamps in fixtures at one end. The effect is surprisingly good, and the room is well lit for all practical purposes. The railroad company had originally installed three large-sized chandeliers with six 16-cp lamps each. These are not now in use at all, the other lamps above mentioned supplying all the illumination.

ELECTRIC HEATING

In a quiet and steady way, electric heating has advanced during the past year. Central-station men do not realize yet their opportunities in this field. It is hardly an exaggeration to say that a great many of them look upon electric heating as experimental or chimerical, whereas nothing could be further from the truth, even allowing that present apparatus is likely to undergo great improvement in the course of the next few years.

Of course, a great many stations to-day can not tell for what purpose their current is used, because they meter it, but it is certainly worthy of note that only 31 stations in 1902 in their returns to the Census Office reported the specific sale of current for electric heating. A great many others are doubtless in the business, but, when all is said, the street-railway field remains still the great exemplar of electric heating. During the past severe winter every car on the whole Manhattan Elevated system of New York was heated electrically, representing at some hours of the day probably not less than 1200 cars. In 1902, more than half of the street-railway cars in the United States were heated, and of the number no fewer than 19,021, or 63 per cent, were heated by electricity. In other words, during the past winter, for months together, and almost down to the month of May, considerably over 20,000 cars have used current for heating several hours daily. In the aggregate this represents an enormous amount of service and current consumption; and yet it might be easily duplicated on central-station circuits. Eighteen years ago, I ventured to suggest to doubting members of this association at Detroit, that there was money in the then infant motor or power service. No one questions that now.

One of the important electrical events of the year has been the equipment of the Government Printing Office in Washington—the largest printing establishment in the world—with the largest electric-heating plant in the world; to say nothing of the fact that there are over 600 power motors in use under the one roof. Mr. W. H. Tapley, the progressive electrical engineer of the Office, with the courage of his convictions has spent a large sum to great advantage on a plant that is really an extraordinary exemplification of the flexibility and economy of electric heating. The work is characterized by a great deal of originality and thoroughness, for which the staff, in conjunction with Mr. W. S. Hadaway, Jr., must be ascribed great credit. The uses of electric heat in the Office fall broadly into two groups or classes. One of these embraces the foundry and includes matrix-drying tables, wax-stripping tables, wax-melting kettles, case-warming cabinets, "builders-up" tool heaters, case-warming table, wax-knife cutting-down machine, "sweating-on" machine, and soldering-iron heaters. The other class in the bindery includes embossing and stamping press heads, glue-heater equipments,

glue cookers, case-making machines, finishers' tool heaters and book-cover shaping machines. This is a remarkable range, but in addition and outside these we find the pamphlet-covering machines, the sealing-wax melters and some other devices. It is only when one sees such an equipment as has been devised for and brought together in the Government Printing Office that one grasps fully the idea of the extraordinary range and utility of electric heating. Such heating may not yet take care of a big building, but in such special applications as these it can not be surpassed or equaled for efficiency and economy.

The equipment of these electrically heated appliances in the Office supplants gas and steam in all processes. Practically all the apparatus was made from new designs by Mr. Hadaway with careful attention to mechanical details, and with large factors of safety electrically. The specifications of the controlling appliances were rigid, and necessitated new switch designs giving great strength and durability. The switches are mounted upon slate slabs and protected by iron covers, all connections being soldered to lugs. The slabs are mounted upon iron or slate bases so that every precaution may be taken against accident. In cases where working temperatures are moderate, the apparatus is operated on 117 volts. Where high temperatures and rapid rates of impartivity are required, lower variable voltages are used. These are secured by translating appliances consisting of rotary converters and transformers with several taps on secondaries. The extreme ranges of energy density in various appliances are from 0.75 watt to 40 watts per square-inch superficial area. The plant gives great satisfaction, and is already being imitated in other large printing offices, notably that now being equipped by the New York *Times*, which will employ a great deal of electric heat, depending upon current furnished from the street mains of the New York Edison company.

Another exemplification of the growing scale upon which electric heating is used, is furnished by the Berg hat factory, of Orange Valley, New Jersey, with a capacity of 300 dozen felt hats per day. There approximately 100 kilowatts or half the entire average output of the plant is used up in the electrically heated devices for making the hats.

Our able past-president, Mr. James I. Ayer, who is devoting

his ability and energy to this subject, showed me recently a photograph of over two tons of electric-heating apparatus he was shipping abroad on foreign orders; followed shortly after by another shipment equally large. Mr. Ayer notes this year, as last, the revelation of the fact that heating is going on unknown to central-station managers, by the fact that complaints are made when circuits have been shut down for overhauling in the daytime. This has been true, for example, at Somerville, Mass., and Newton, Mass. Mr. Ayer notes in general an increase of orders and inquiries both from central stations and from factories.

One incident reported to me by Mr. Ayer of the advantage of electric heat over other methods was conspicuously developed at Harvard Memorial Hall, which is the dining-room of many students of Harvard University (about 1500 regularly take their meals there), by the introduction of electric waffle irons, displacing gas irons. Electric waffle irons, being heated on both sides at once, produce a more perfect product and do the work more quickly than with gas. In the regular operation of baking waffles, batter is poured into half of a mould, the other half being closed over it, and in the case of gas the heat is applied on one side for a period. Then the mould is turned over and the heat applied to the other side. With electricity, the heat being supplied on both sides by having each half of the mould directly heated, this turning is avoided.

To prevent the waffle sticking to the iron, it is necessary to apply oil or lard. In the case of a gas iron, much of this oil gets on the outside of the iron and is converted into smoke by the flame. In the case of electric irons, no such loss occurs and no such smoke develops. On account of irregular heating, it is frequently necessary to open the mould of the gas iron to test the progress of the baking. In the case of electric irons, this is totally unnecessary, as the time element is definite, and the moulds are not opened until the prescribed time has elapsed.

It was found that for serving the students, where there was demand for about 250 waffles in one hour, one operator with the electric irons could do the work of two with gas; the smoke nuisance was eliminated, the saving in oil was considerably more than half that required for gas, and subsequently, recent improvements in electric waffle irons have resulted in the elimination of

the use of oil entirely. Another curious thing is that it takes about 20 per cent less batter with the electric iron for the same number of waffles that was required with the gas. The reason appears to be that the cooking is done much more quickly; hence a lighter article is produced.

THREE-PHASE CENTRAL STATIONS

With regard to methods of distribution, it should be noted that last September the city of Dublin, Ireland, put into operation a very interesting four-wire, three-phase distributing system, to the displacement of a single-phase system. The new system is, it is believed, the largest of its kind in the world, although we have three-phase, two-wire systems in cities like Sacramento and Salt Lake City. The old system was started by the municipality in 1892, and at the time of its displacement had connected the equivalent of 16,500 16-cp lamps. The old plant had a primary voltage of 2000 with a secondary pressure of 100 volts, and operated with 83 cycles per second. In addition, some street lighting was provided by arc machines. The distribution has been underground from the beginning. The first cables that were laid decayed rapidly, and in 1899 an entirely new system was laid; the secondary pressure changed from 100 to 200 volts, and instead of each house having its transformer, all transformers were grouped into five substations. The system, as operated, never gained favor, and it was finally decided to put in an entirely new plant, though $400,000 had been expended on the old one. As above stated, the system adopted is a four-wire, three-phase system. Primary current is generated at the entrance of Dublin harbor at 5000 volts, and transmitted to a substation in the city. The secondaries of the substation transformers are star-connected, the old 2000-volt mains being connected on separate phases between the outer points and centre point. Twenty new substations are being added, which will supply 200-volt networks, the lamps being connected between the outers of the star and the neutral common return to the centre of star. The arcs are supplied with direct current through motor-generators.

The old lighting system was single phase, current being supplied at 2000 volts from the main substation to five substations, from which low-tension, single-phase networks were

fed at 200 volts. These substations and networks are retained, and are, in fact, still fed from the old switchboard at the main substation, the step-down transformers already referred to being employed to change the pressure from 5000 to 2000 volts between the two switchboards. For this purpose three 250-kw, single-phase transformers have been provided, with a fourth one as spare, and also four 50-kw transformers (one being spare) for the light-load periods of the day. The primaries of the transformers are delta-connected, and the secondaries star-connected, the middle of the star being earthed. The secondary terminals of the transformers are directly connected to the old high-tension board, so that each group of three takes three independent circuits. Any motors on these circuits must be single-phase, and the new motors which come on will all be connected to the new three-phase secondary networks.

The new three-phase circuits are fed from the 20 overground substations, where the current is transformed down to 200 volts, the primaries of the transformers being mesh-connected and the secondaries star-connected, 200 volts being the pressure between the outers of the star and the centre point. The secondary networks are all distinct and not interconnected, and four-core cables of various sections are employed for distribution. The lamps are placed between one of the conductors cennected to the outer of the star and the fourth conductor, which acts as a common return for the three phases, and is joined to the centre of the star and earthed. Theoretically, if the three circuits were perfectly balanced, no current would flow back through this conductor, but in practice it appears that the circuits will be far out of balance; so that the four cores have been given equal section. The motors are to be connected across the phases without the neutral wire being employed. The main reason for the adoption of this system is that it allows of a higher pressure between the three conductors corresponding to the three phases than if the lamps were simply connected on the three phases in the ordinary way. Two hundred volts has to be supplied at the lamp terminals, and by this four-wire connection the pressure between the three main conductors is 346 volts. Thus, even with four conductors of equal section, the total weight of copper employed is diminished. On the other hand, each conductor has to be better insulated, and, what is more important, the method

of connection introduces more complications in the junction boxes and increases their size. The low-tension cable is laid in the same manner as the high-tension cable, except that when the troughing is under the footways its thickness is reduced to .25 inch. In connection with this plant, I may perhaps be permitted to quote briefly an editorial reference to it from the columns of my own journal, as follows:

"It is interesting to see an unmitigated polyphase system tried on a large scale under the severe requirements of modern urban distribution. The three-phase star with neutral wire is, perhaps, upon the whole the most promising alternating system for use upon a large scale. It is not quite so simple as a two-phase, four-wire distribution, but saves a large amount of copper, almost as much as an ordinary three-wire, continuous-current system, even with the large neutral used in Dublin. Broadly, all distributing systems which save copper by combining circuits involve in one form or another the ques- of balancing the load to insure uniformity of voltage. In the early days of the three-phase system great importance was attached to this matter, and it was an objection often strenuously urged. As experience has been acquired, the fear of unbalancing has sunk to its proper plane, and it has been found that with reasonable care there was little to fear. On a distribution fully laid out for three-phase circuits, this load-wandering can be deprived of its injurious tendencies; but where, as in part of the Dublin system, three old single-phase circuits are put in three-phase connection without any material change, there is a considerable possibility of trouble. This sort of thing can be successfully done in cases where it is a very small part of the total load or where, as in wiring large buildings, the secondary drop is rather small; but it must be rather carefully watched, and should be worked over to a pure three-phase form when opportunity offers. The connections are a trifle more complicated in a three-phase system than in an ordinary three-wire system, but the difference is practically inconsequential, and, with due care, as good service can be given from one as from the other. Certainly, the new Dublin system will be a vast improvement over the old one, and we doubt not that the results will be highly satisfactory. The frequency is dropped in the new plant to 50 periods, which seems to be becoming rather the standard practice

abroad. Here there is a double standard, 60 periods for general service and 25 periods for work with rotaries. Where many motors are to be used or where much of the distribution is to be underground, there is a material advantage in dropping the frequency below 50 periods; but where lighting is to be done by the alternating current, 25 periods is too low. Perhaps there is no single standard frequency that can be settled upon in general practice in view of the complicated requirements, but it would certainly be an advantage if the bulk of the work could be done at a medium frequency which would enable the bulk of the machinery to be available for all purposes. As it now stands, an enormous variety of machines are built to furnish a fairly complete line at each frequency in use, and it would be a good thing if there were greater uniformity in the matter of frequency."

A number of topics have been discussed in this brief report, but it is needless to add that they are few in comparison with those which might be treated. Several of the subjects that have been reserved for discussion have, I notice, been made the subjects of elaborate papers by competent authors; and it has seemed to me therefore that I should be economizing the time of the convention by not making this report any longer than it is. The last two or three conventions have seen a wide extension in range of topics treated in the papers, the *Question Box*, and other departments, and hence the work of the committee on progress becomes limited, much to its relief—probably also to yours. It might be noted in conclusion that when the association last met in Boston, in 1887, one great feature of the convention was the discussion of the utilization of electric motors on central-station circuits. A vast outgrowth dates from that convention, and it is similarly to be hoped that the present convention, 17 years later, may also serve as a landmark of central-station progress along new routes.

DISCUSSION

THE PRESIDENT: We have with us to-day one of the earliest presidents of the association; I think there have been thirteen presidents between himself and the present administration. I am going to ask Mr. Edwin R. Weeks, of Kansas City, to address you, and possibly to make incidental reference along the line of the report of Mr. Martin, which we have just heard, as Mr. Weeks was a pioneer in the industry.

Mr. Weeks: Mr. President and Gentlemen—While we should always welcome the new member, for whom all things are reserved and without whom this association would soon lose its usefulness and would cease to exist, I may be pardoned, as one of the "Old Guard," for expressing some of the pleasure that I feel on finding on the roster of this convention the names of so many of our original members. The presence of these names should also be a source of gratification to all, as it evinces a very desirable continuity of interest in the work of the association. It is also a forcible reminder of the fact that the electrical industries, now comprising investments running into the billions, have sprung up and grown to this vast estate well within the compass of one generation; that the majority of even the seniors among the great investigators and inventors—like Thomas A. Edison, Elihu Thomson, Edward Weston, Charles F. Brush, Frank J. Sprague—are still young men, actively engaged in enterprises of great pith and moment. Yet the highly original work of these men and of their contemporaries and followers lies at the very foundations of the electrical industries of to-day.

This association is unique in the extent to which the scientific or technical and the commercial elements have united under its banner. It may be likened to the fable shield which, you may remember, was both gold and silver. It has had, in harmonious combination, the gold of pure science and the silver of practical application. Contributing to its proceedings have been men like Rowland, who, with little attention to commercial considerations, devote their lives to study and experimental research; and men of affairs, like my old friend Perry, of Providence, who have put hundreds of millions into applied electricity and who overlook none of its financial phases.

Much could be said of the advantages of membership in this association; but it is rather of the greater good accruing to the engineering professions and to the world at large from associated effort that I am reminded on this occasion. Modern electrical researches and investigations, furthered in many ways by the work and by the influence of this association, have given a quickening impulse to all trades and professions and have created an intellectual expansion without parallel in history.

This association is not yet of age, but its lines have fallen in stirring times and in places where much honor was to be won. Its older members, reviewing the early trials and brilliant achievements of almost the entire field of applied electricity, may say, "All of this we saw, much of this we were"; and its younger members may face the future with the certainty of still wider commercial applications and the necessity for higher professional attainments.

The electrical industries still lead the van of human progress. The electrical engineer, in the highest sense of the word, is the resultant of all engineering experience, and to the engineers of the world—if I may include inventors as engineers—more than to all other professions combined, the civilization of the present day is due.

This association is to be congratulated on its growth and increasing influence, and the first session of this convention, in its enthusiasm and unusually large attendance, is certainly a great and richly deserved compliment to our honored president. (Applause.)

THE PRESIDENT: Is there any further discussion on Mr. Martin's paper? We are running on a schedule, but we have plenty of time just now.

MR. E. F. McCABE (Lewistown, Pa.): I would ask a question of Mr. Martin. He gives the total amount invested in electric-lighting companies as $504,000,000; he gives the gross income as $85,000,000 and the expenses as $68,000,000, leaving a net income of $17,000,000 on an investment of $504,000,000. I shall be glad if Mr. Martin will inform us if he is sure that those figures are correct.

MR. MARTIN: I have no reason whatever to question the accuracy of these figures, as they are based upon your own statements, gentlemen, made to the Census Office in Washington and compiled there. I am sorry that the industry as a whole does not show up at a higher rate of yield upon the investment that has been put into it in the last fifteen or twenty years. But you must determine for yourselves what the real return upon the investment is and to what extent the figures recorded may represent water and inflation.

MR. SAMUEL SCOVIL (Cleveland): I ask Mr. Martin to add the words, *and experience*.

MR. MARTIN: I catch the point that Mr. Scovil makes, and should like to say that I heartily indorse the idea he wishes to convey, namely, that in the organization of our electric-light companies, our telephone properties and our street-railway properties the capitalization should represent the experience; it should also represent the foresight, the courage, the ingenuity and the inventiveness, that go to create these properties. These elements are just as much factors in the development of the property—although less easy to estimate as to value—as are the dynamos, steam turbines and pole lines that constitute the physical part of the plant. I believe that in the state of Massachusetts this intellectual part of the operation is not recognized, and it surprises me that the state of Massachusetts should be the very one to fall down upon that idea.

MR. ARTHUR WILLIAMS (New York): I am one of those who did not get a copy of this very interesting report before the opening of the convention, and therefore have not yet had an opportunity to go fully over its contents. I regret that this is one of the papers to be read by abstract, because, so far as I have read it, it seems one of the most interesting ever presented before the association. In a report of this nature a great deal of good can be obtained through a public reading and discussion. Through this paper we are advised of the progress made in the industry all over the world since our last meeting; it is a world-report.

One suggestion occurs to me with reference to the Nernst lamp. Mr. Martin speaks of this lamp as having made satisfactory progress in a field already pretty well covered by competitors. There is a point in this field of lighting that is not covered by competitors of the Nernst lamp—the point that lies beyond the largest size of incandescent lamp that can be used conveniently and the smallest arc lamp that will burn with satisfactory results. This gap the Nernst lamp of three and six glowers fills most satisfactorily, and at this time it does not seem here to have any serious competition. The Nernst lamp in combination with the ordinary incandescent light, which is more yellow in color, gives very pleasant results. I recall a room in a club, used largely for the exhibition of pictures, where no light has been so satisfactory for this purpose as that composed of Nernst light from the ceiling and incandescent light from the cornice of the room.

It was reported a year ago that in England more than 400,000 Nernst lamps of various sizes, mostly the larger, were in use for interior and outdoor lighting. The outdoor or municipal lighting was said to be very satisfactory. The English experience has been that the large sizes of this lamp have the greater field. Because of the low standards of incandescent light the smaller sizes of Nernst lamps have had greater opportunity than I think they would have here.

MR. MARTIN: With regard to the statement of Mr. Arthur Williams respecting the illumination of art galleries, I think it deserves mention that the art galleries at the St. Louis Exposition depend for their illumination upon the Nernst lamp, and those of us who have seen the brilliant white light which that lamp gives can not, I think, conceive of a lamp more appropriate for such uses and purposes. At the other extreme we have, if I may venture to say so, the Cooper Hewitt mercury-vapor lamp and lamps of that generic type. I would hardly recommend them for an art gallery, although you have been invited to participate in the performance of one in a photographic gallery.

There is in New York city a most striking exemplification of the utilization of the Cooper Hewitt lamp, and I think anyone who sees that would say at once that in that particular respect and at that particular point the Cooper Hewitt lamp has certainly a sphere of usefulness. I refer to the large storage-battery-charging room at the New York Vehicle Transportation Company; a room 250 to 300 feet long, about 40 or 50 feet wide, and some 40 feet in pitch. The arc lamps that have been placed in that room have given a very poor and inefficient illumination, and there has always been trouble present due to the sulphuric-acid fumes from the batteries. It was decided at last to install Cooper Hewitt lamps in place of arcs. The current consumption has been cut in two. The lamps have been in use some four or five months, and I can say from my own observation, though not from any photometric demonstration, that the illumination of the room is infinitely superior to anything attempted before. The room is dark, the battery boxes are black, and the difficulties in the distribution of the light are very serious and considerable. The new light is efficient, it is economical, and the "greenery-yallery" rays of the

lamp, which have been said to add a new terror to death, are certainly doing their duty and doing it very advantageously in that room. I can imagine a great many car depots, a great many electric-lighting plants, a great many semi-dark inclosures, where the Cooper Hewitt lamp will have a fine and very advantageous field of use, and where the arc in its present form has not altogether filled the bill. At the same time, the lamp has its uses outside of that sphere of usefulness. I merely wish to emphasize the illumination in question, because I have attempted to include in my report a picture of the room and of the illumination referred to, and, while the picture suffers from the process of reproduction, I think you will agree with me that for a room of that size the illumination shown in the cut is highly satisfactory.

THE PRESIDENT: We will now take up the paper on "A Three-Wire Five-Hundred-Volt Lighting System," by Mr. Walter I. Barnes, of Providence. I presume you know that this is a method of lighting generally in vogue in England, but it has made very little headway in this country. The only company that has used it effectively and for a long time is the Narragansett company, of Providence. Mr. Barnes is connected with that company, and I have pleasure in presenting him.

The following is the paper read by Mr. Barnes:

A THREE-WIRE FIVE-HUNDRED-VOLT LIGHTING SYSTEM

"Those who know best what is required to meet all issues and to establish a business, including the complex factors and conditions assembled in undertakings for central-station work, are those who have invested their money in it and are employed daily in its management."

With slight changes in form this precept might well be applied to any commercial or financial enterprise; as originally voiced, however, its particular and peculiar application was the central station for supply of electrical energy. The speaker of that occasion surely did not have in mind the details of any possible future development in the properties under his management, but he certainly did realize that there were many issues to be met and that the complex factors and conditions were frequent, and his evident purpose was to rid the situation of its complexities and to establish a business on an efficient and well-disciplined organization. The date of this wholesome utterance was August 19, 1890, at a meeting of this association, the speaker being the then president of the association, Mr. Marsden J. Perry, who was then and is now the general manager of the Narragansett Electric Lighting Company, Providence, Rhode Island.

At that time, other than for the companies operating under the Edison organization, with perhaps a few exceptions, there was but one path to follow where multiple distribution of electrical energy was concerned, and that was the two-wire system, using either the direct or alternating current.

The two-wire system, for obvious reasons, was almost entirely neglected except for motor systems operated at 500 volts direct current, and the field was practically given up to alternating-current distribution.

The manufacturers of electrical apparatus 14 or 15 years ago were not unwilling to dispose of their product, and the salesman most appreciated, if one may judge by results, was he who sold the greatest number of small generators and diminutive transformers. In one case, at least, the argument was used by the representative of a well-known manufacturer

that by using generators of low capacity and transformers of small units, the chances of a general interruption of service were materially lessened, as one burnt-out generator or transformer would affect but a small part of the system. Whether or not the argument above noted was generally used, the result seems to have been accomplished, for it was not at all uncommon in the early part of the last decade to find alternating-current systems in large cities where the largest single transformer did not exceed three kilowatts capacity, and the fashion seemed to demand even smaller units.

The incandescent lamp of the times was on the borderland of voltage. Some of the manufacturers declared boldly for the 100-volt type, yet acknowledged the better efficiency of the 50-volt standard of preceding years. With two lamp voltages in the market, the central-station manager alive to the situation demanded transformers that were equally well adapted for use with the lamps of either voltage, the result being the three-wire transformer, which made possible a considerable saving in copper when three-wire, 50-volt, secondary mains were considered, or when used with two-wire mains at 100 volts.

While the transformer engineer was devoting his energy to lessening the fixed losses and improving the regulation of the transformers, the lamp manufacturer was bending every effort to produce a lamp of better economy than heretofore, which would give a fair and reasonable life when subjected to the conditions of transformer regulation then existing. The result, although by no means perfect, was highly satisfactory in comparison with past records, so that in 1896 to 1898 the 100-volt type was the equal, if not the superior, of the 50-volt lamps of two years previous. With this fact well established, the natural inquiry of the interested middleman between manufacturer and consumer was, if the 100 and 110-volt lamp so soon supplanted the 50 and 55-volt type, why may we not have 200-volt or even 220, and possibly 250-volt lamps, and still further decrease the copper investment?

In 1897 the commercial 220-volt incandescent lamp was yet in the future; in 1899 the 250-volt lamp was in increasing demand, and the first American installation of any magnitude using the so-called high-voltage lamp was made under the engineering advice of Mr. Bion J. Arnold in St. Louis, Missouri, and

is fully described in a preliminary paper at the Omaha meeting of the American Institute of Electrical Engineers in June, 1898, although the system was not in commercial operation until some months later. Owing to certain legal obstructions it was inadvisable for the St. Louis system to be installed as a pure three-wire arrangement, and it was left for the Narragansett Electric Lighting Company to be first in the field using a direct-current, three-wire feeder-and-main system with grounded neutral.

The original request of the general manager called for a report on a five-wire system using 125-volt lamps and a three-wire system using 250-volt lamps, and a joint report was presented by Mr. Wm. C. Woodward, the electrical engineer of the Narragansett Electric Lighting Company, and Mr. B. J. Arnold, in May, 1899.

The immediate decision of the manager was in favor of the three-wire system. With the 250-volt lamp as a factor in the situation, the alternating-current transformer was no longer a necessary part of the system, for, wherever a 500-volt, two-wire system could be operated to advantage, it was at once possible to modify the arrangement so as to allow of the use of a three-wire, 250-500-volt system.

In 1899 the Narragansett Electric Lighting Company had a connected load of 9000 kilowatts, of which 4900 kilowatts was in alternating-current multiple distribution, 2700 kilowatts in direct-current, 500-volt motors, 400 kilowatts in series commercial arc lamps, and 1000 kilowatts in series arc lamps on city contracts. The electrical generating equipment consisted of three 500-kw, alternating-current, 60-cycle generators, three 500-kw, direct-current, 500-volt generators, 16 Thomson-Houston series generators, 50-light capacity each, and 18 Fort Wayne series generators, 125-light capacity each.

A city ordinance relating to overhead wires required that all overhead construction of the Narragansett Electric Lighting Company within the close fire district of the city should be removed within three years from the passage of the Act. This necessitated the removal of 600 poles and about 160 miles of wire in any event, and as the company, for the benefit of the service, proposed to extend the district prescribed by the ordinance, the amount of territory was voluntarily increased about 100 per cent.

In general, the proposed reconstruction provided for, first,

the construction of a complete underground system; second, an installation of a storage battery; third, the discontinuance of the alternating-current system in the close fire district and some adjacent territory; fourth, the discontinuance of the commercial series generators; fifth, the removal of the poles and wires as required by the ordinance.

The construction of the conduit system was begun in October, 1898, and continued until December, 1901, during which time about 40 miles of streets were opened and 1,700,000 feet of ducts were laid. Of this amount about 1,000,000 feet are single-duct and 700,000 feet, multiple-duct. There were built about 850 manholes of an average size of six feet square and seven feet deep. The general construction of the manhole is shown in Figure 1. The ducts that were used in the underground system were laid on a three-inch bed of concrete, which was spread on a spruce-board bottom; the side walls beyond the ducts were of concrete three inches thick and well-rammed between the side boarding and the ducts. Over the ducts was a three-inch layer of concrete, above which was placed a protective layer of creosoted plank an inch and a half thick. After laying, the ducts were all rodded and cleaned, ready for drawing in of cable.

Owing to the peculiar location of the streets along the river front, the conduit system was often constructed below tide level, and it became necessary to waterproof the system of conduits and manholes where the same were close to the water front. This was accomplished by building 12-inch side walls on the concrete bottom of the trench, and covering the side walls and concrete with several layers of tar paper laid in hot asphalt. The waterproofing of the manholes was accomplished in a similar manner, and the results indicate that such a method is perfectly satisfactory. The illustration in Figure 2 shows method of conduit construction.

Into this system of ducts there was drawn about 2,000,000 feet of cable, varying in size from No. 14 B. & S. gauge, used as potential wires, to cables having an area of 1,000,000 circular mils, used as tie lines between generating and battery stations. Rubber-covered cable only was used, the insulation being Okonite, varying in thickness from five-thirty-seconds to nine-thirty-seconds of an inch, according to purpose for which it was intended. The five-thirty-seconds-inch insulation was used in the three-wire system. For the alternating-

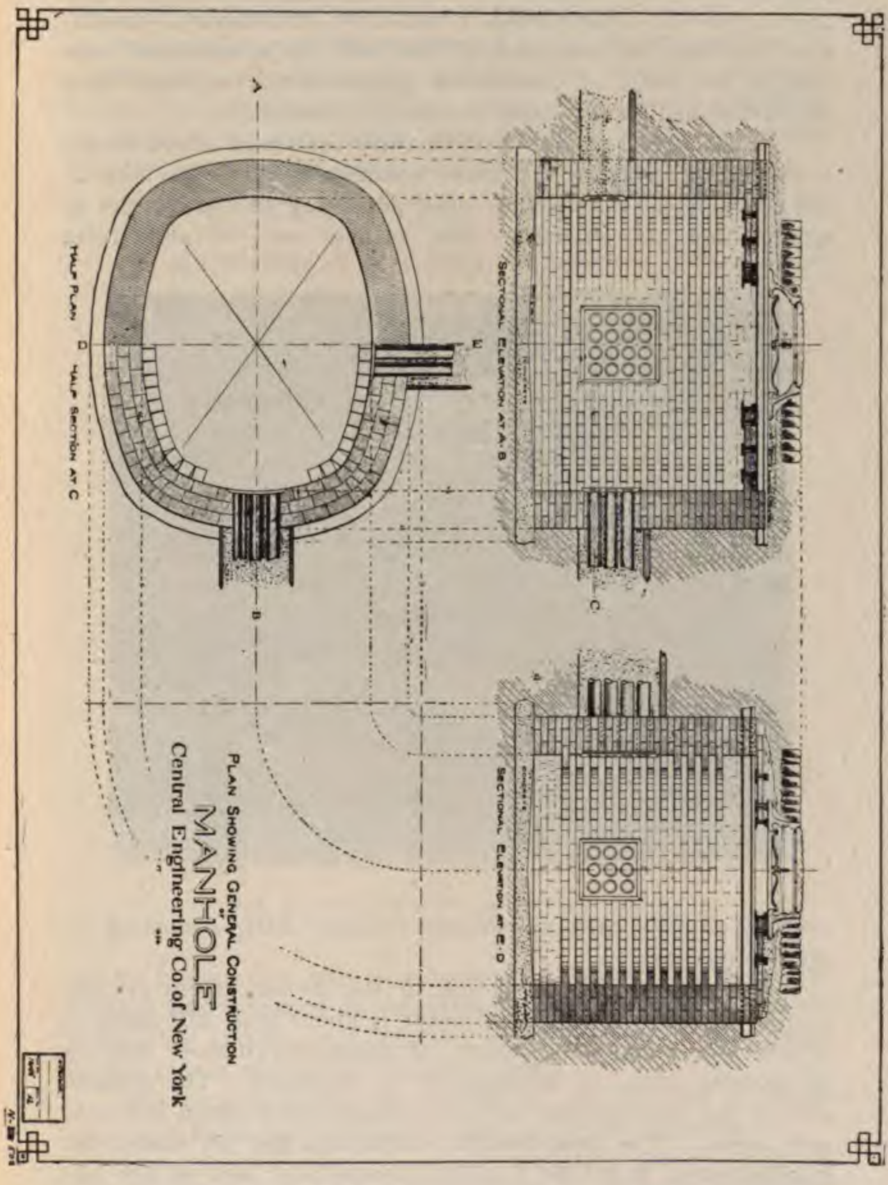

FIG. 1—GENERAL MANHOLE CONSTRUCTION

current, 2200-volt system, and in the constant-current, 6050-volt system, the insulation was seven-thirty-seconds, and in the 11,000-volt transmission circuits the thickness of insulation was nine-thirty-seconds of an inch. It is worthy of note that in five years of continuous operation not a single fault has developed in the cable or conduit system.

In the direct-current system there was used about 1,100,000 feet of cable. The main conductors have an area of 200,000 and 300,000 circular mils, according to the district in which they are situated. The feeders vary in area from

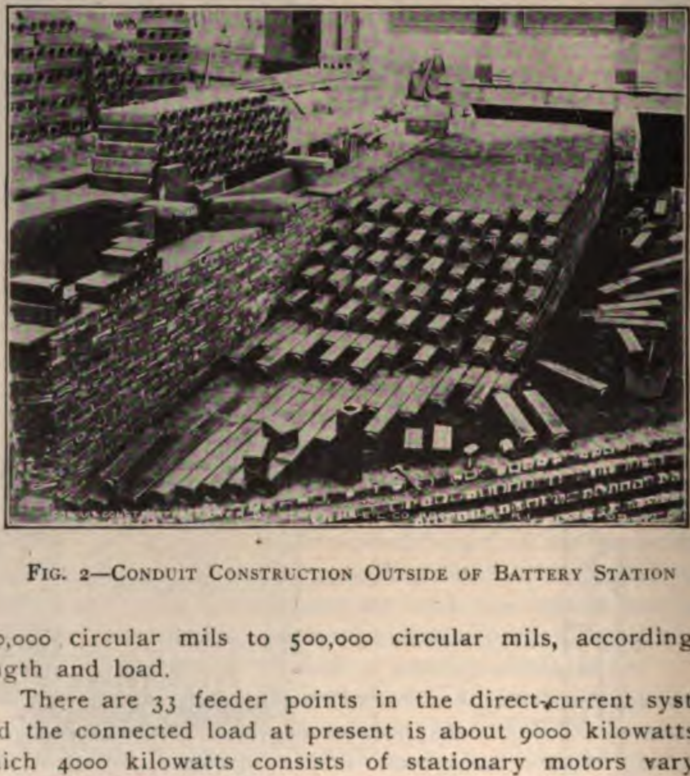

FIG. 2—CONDUIT CONSTRUCTION OUTSIDE OF BATTERY STATION

200,000 circular mils to 500,000 circular mils, according to length and load.

There are 33 feeder points in the direct-current system, and the connected load at present is about 9000 kilowatts, of which 4000 kilowatts consists of stationary motors varying in capacity from .25 kilowatt to 75 kilowatts. The remainder of the load consists of 80,300 incandescent lamps and 1280 arc lamps. The incandescent lamps average 3.3 watts per candle-power, and have a useful candle-hour area of not less than 4000 hours, assuming the smashing point to be 80 per cent of the initial candle-power.

It is quite interesting to recall that in 1899 the average watts per candle varied from 3.8 to four watts, and at that time the candle-hour area did not exceed 2900 hours.

The arc lamps in use at present are of the twin-carbon, inclosed type, and operate in multiple on 250-volt circuits—that is, two arcs in a single inner globe—the current averaging 2.3 amperes, the energy per lamp averaging about 575 watts. This lamp has proved quite satisfactory, and is much to be preferred to the single-carbon lamp, in which the volts at the arc are about 160.

For the purpose of producing the best possible regulation

FIG. 3—GENERAL VIEW OF BATTERY ROOM

of the system and also to tide over the peak load, a storage battery was installed at a substation about 2400 feet from the generating station, in a location which in time will be fairly in the centre of the distributing system.

The battery (Figure 3) consists of 296 cells of 43 plates each, the eight-hour discharge rate being 840 amperes.

The cells are mounted on an insulating system (Figures 4 and 5), which has served to annihilate the various troubles often found in battery insulation. A double tier of porcelain

insulators is used; the first tier is mounted on four brick piers, which are capped with a hard-pressed tile thoroughly impregnated by boiling in paraffin; triple-petticoated porcelain insulators are then placed on the tile. . Longitudinally with the cell and resting on the four insulators are placed two hard-pine sticks, four by four and three-quarters inches, well painted with an acid-proof paint. On each of these hard-pine sticks are placed three tiles boiled in paraffin, and resting on these tiles is a second tier of porcelain insulators, which, in turn, support the battery tanks. The distance from the floor to

FIG. 4—SYSTEM OF INSULATION OF BATTERY CELLS

the bottom of the tank is 20.75 inches. The floor under each cell is pitched from a point under middle of cell to the aisle between the cells at an angle of about 20 degrees. This allows any surface water or dripping from tank to drain off rapidly.

Frequent washings of the floor immediately under the tank and systematic cleaning of the insulators that may be conveniently and safely reached, have served to produce the best results in practice, the leakage to earth being entirely eliminated.

The battery is seldom discharged in regular service to

exceed the three-hour rate, and then only for a period of about an hour. The load on the system is so evenly balanced that seldom does the unbalanced condition exceed three per cent of the load appearing, and the neutral conductor is of ample capacity, even should the unbalancing greatly exceed the figure given. In order, however, that the battery may be always in balance as near as possible, a balancer generator is to be installed.

While the conduit system and the storage battery were being installed, active preparations were being made whereby existing installations on the alternating-current, two-wire system might be readily transferred to the direct-current, three-wire system.

As the 250-500-volt, three-wire system that it was proposed to install was a radical departure from all standards then existing, every precaution was taken to obtain the best and safest results. It was decided to re-wire most of the older installations, and although in many instances the wiring in customers' premises called for but slight modification, yet there were other cases where the entire wiring equipment was replaced.

Certain types of fittings were adopted as standards, so that the installations might be uniform throughout the entire territory. The Edison type of fibre-lined socket with a mica disc under centre contact was adopted as a standard socket. Inclosed fuses of plug and cartridge type were used to replace open-link forms of by-gone days. Modern switches took the place of older patterns, and iron or steel pipe was generally used to replace the wooden moulding of previous years.

There was naturally found a great saving in the amount of copper used in the new system, which was of great benefit to the consumer. In re-wiring some old installations it was not unusual to find two or perhaps three No. 0000 wires in each side of the mains, run in a heavy moulding from transformer to centre of distribution, the installation having been made in the old days of 4.5-watt, 50-volt lamps. These conditions were in marked contrast to the small iron pipe run from manhole to centre of distribution, and the three No. 10 wires that were drawn into same and supplied an equal amount of energy as in the case just mentioned.

Aside from the very material view of the investment saving under the new arrangement, there is the aesthetic

viewpoint, which is much better satisfied in the improved construction made possible by the features of the present system, which tend to, and do, produce a neater, safer and more compact installation.

The several sections of the city that were included in the changes were served with about 50,000 incandescent lamps, 1000 arc lamps and 2000 kilowatts in stationary motors, and these installations were reconstructed to comply with the requirements of the new system; the change from aerial to underground supply, and from alternating-current to direct-

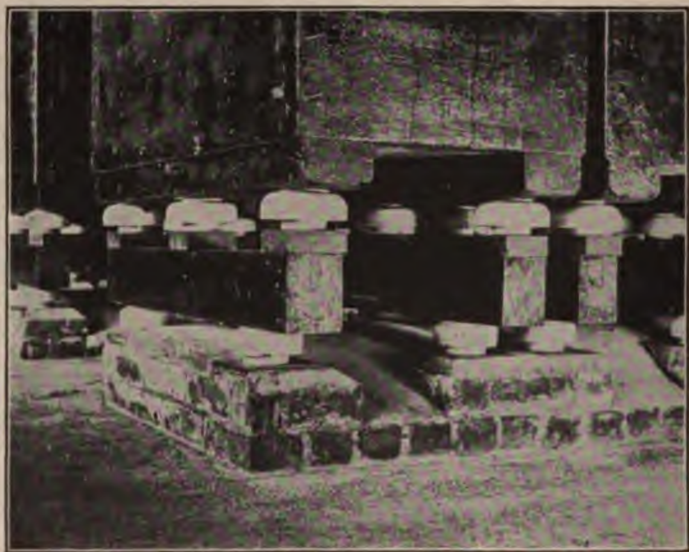

FIG. 5—SYSTEM OF INSULATION OF BATTERY CELLS

current service, was made without any interference with the customer.

The commercial series arc lamps being replaced by multiple arc lamps of the new type, the series generators were released from service at the central station.

The arc lamp situation was at first rather perplexing, as none of the larger manufacturers were inclined to provide such a lamp as was demanded. A local manufacturer finally produced a lamp that was the forerunner of those which are now generally used.

All motors of the direct-current type are connected to the

outside or 500-volt wires, and although these motors operate devices that are subject to wide and sudden changes in load, yet the lighting service is in no way affected by such disturbances of load condition.

By referring to the diagram in Figure 6 the relative copper economies of the voltage orginally used and the one used in present work are fully demonstrated. The distances to which any given amount of energy may be transmitted at a given loss are also indicated in this diagram, and when it is recalled that the three-wire system under consideration has a difference of potential of 500 volts between the outside wires, it is plainly evident that a very considerable area may be covered economically at this voltage. For sake of illustration, the area covered by the Edison three-wire system using 125-volt lamps being assumed as a basis, the area covered by a system such as described in this article would be 16 times as great.

In a central station already operating a two-wire, 500-volt motor system, the addition of a third wire is all that is necessary to obtain an efficient and a flexible wiring system for lighting purposes. The fact, too, that the same generating apparatus may be used for both motor and lighting service is no small factor in the situation, the natural motor load being a day load, while the lighting load, generally extending well into the night, serves to produce a very satisfactory load curve, particularly if a properly proportioned storage battery forms part of the equipment.

The direct-current load curve of the Narragansett Electric Lighting Company is of such a character that during 17 hours out of the 24 a 2000-kw unit could be operated under advantageous conditions.

Owing to the hurried preparation of this paper, the several subjects have not been treated in as connected an order as the author had originally intended, but before closing a reference may well be made to the personal and property hazard incident to a three-wire, 500-volt system.

The management of the Narragansett Electric Lighting Company, realizing that the public was to be given every consideration in the matter of protection, laid the plan of the proposed system before recognized authorities on fire hazards, and received their approval for the undertaking of the work.

The personal risk was also fully discussed, and it was deter-

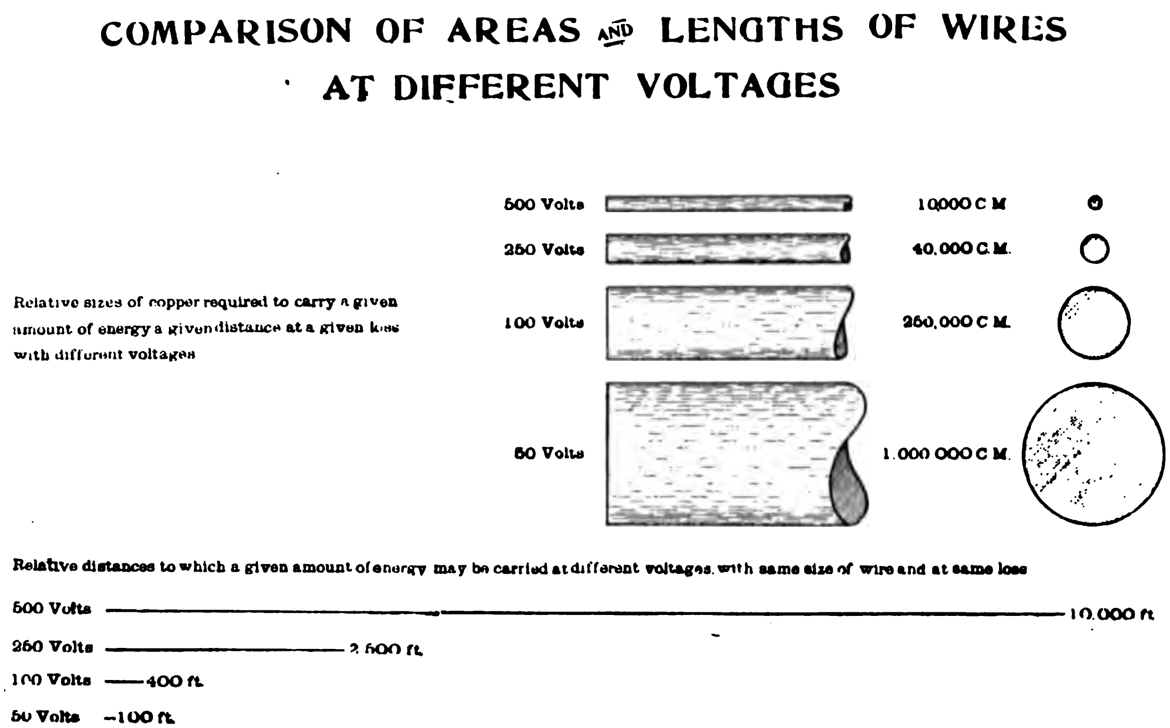

FIG. 6—SIZES AND LENGTHS OF WIRE AT DIFFERENT VOLTAGES

TABLE OF SIZES OF SERVICE LATERALS

NARRAGANSETT ELECTRIC LIGHTING CO.

250 · 500 Volt System.

3 WIRE-LIGHTING							2 WIRE-MOTORS					
AMPERES	DISTANCES IN FEET						H P OF MOTORS	DISTANCES IN FEET				
		10	20	30	40	50		10	20	30	40	50
10	Calculations are based on	No.10	10	10	10	10	1 to 5	No. 10	10	10	10	10
15	.224 ampere per 16 C P lamp	No.10	10	10	8	8	6 to 10	No. 10	10	8	8	8
20	at 250 volts or 8.94 lamps	No 10	10	8	8	8	11 to 15	No. 6	6	6	4	4
25	per ampere on outside of 3	No.8	8	6	6	6	16 to 25	No. 4	4	0	0	0
30	wire system.-500 volts.	No.6	6	6	4	4	26 to 50	No. 0	0	0	0	0
35		No.6	6	4	4	4	51 to 75	150,000	150,000	150,000	150,000	150,000
40		No.6	6	4	4	4	76 to 100	200,000	200,000	200,000	200,000	200,000
45		No.4	4	0	0	0						
50		No.4	4	0	0	0						
75		No.0	0	0	0	0						
100		No.0	0	0	0	0						
150		No.0	0	0	0	0						
200	300,000 C.M. For all Laterals up to 75 Feet.											

Distances given are from Mains to Service Box

Wire sizes in B. & S. Gauge and Circular Mils. All conductors larger than No. 6 are stranded. Insulation, Okonite-5/32 in. wall, 1/10 .n. lead

Breakdown strain 10,000 Volts A. C.

FIG. 7—TABLE OF SERVICE LATERALS

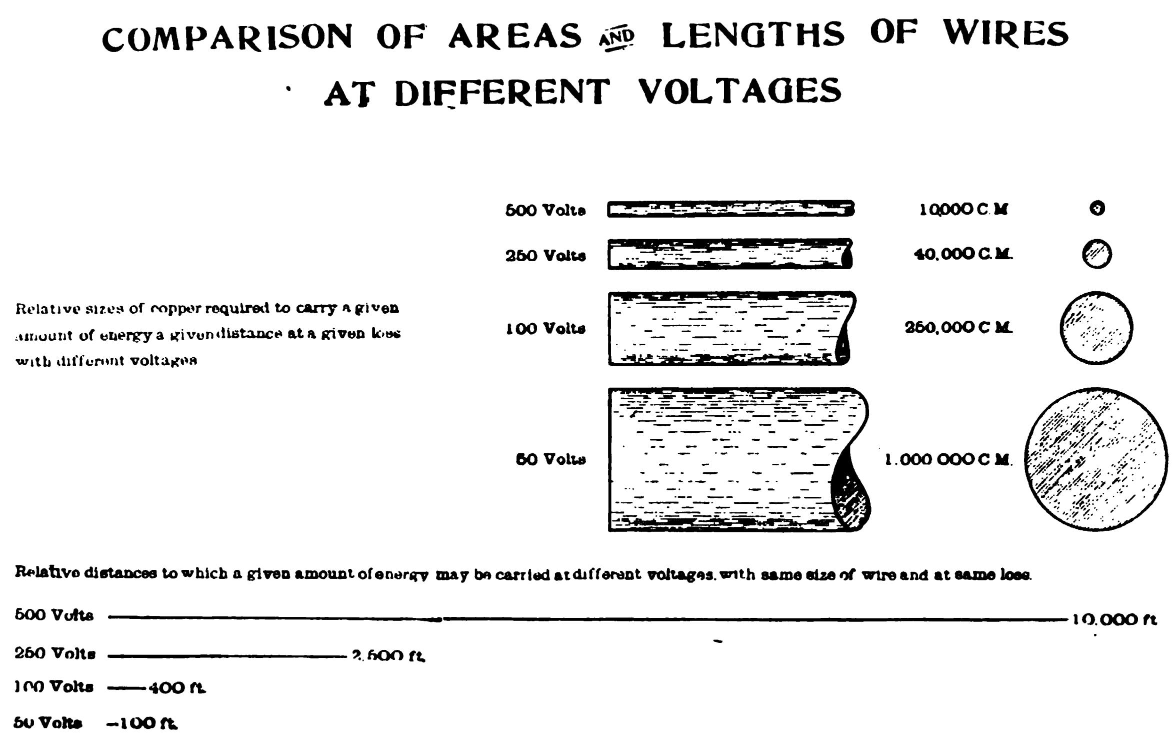

Fig. 6—Sizes and Lengths of Wire at Different Voltages

TABLE OF SIZES OF SERVICE LATERALS

NARRAGANSETT ELECTRIC LIGHTING CO.

250 · 500 Volt System.

3 WIRE-LIGHTING							2 WIRE-MOTORS					
AMPERES		DISTANCES IN FEET					H. P. OF MOTORS	DISTANCES IN FEET				
		10	20	30	40	50		10	20	30	40	50
10	Calculations are based on	No. 10	10	10	10	10	1 to 5	No. 10	10	10	10	10
15	.224 ampere per 16 C P lamp	No. 10	10	10	8	8	6 to 10	No. 10	10	8	8	8
20	at 250 volts or 8.94 lamps	No. 10	10	8	8	8	11 to 15	No. 6	6	6	4	4
25	per ampere on outside of 3	No. 8	8	6	6	6	16 to 25	No. 4	4	0	0	0
30	wire system -500 volts.	No. 6	6	6	4	4	26 to 50	No. 0	0	0	0	0
35		No. 6	6	4	4	4	51 to 75	150,000	150,000	150,000	150,000	150,000
40		No. 6	6	4	4	4	76 to 100	300,000	200,000	200,000	200,000	200,000
45		No. 4	4	0	0	0						
50		No. 4	4	0	0	0						
75		No. 0	0	0	0	0						
100		No. 0	0	0	0	0						
150		No. 0	0	0	0	0						
200	300,000 C.M. For all Laterals up to 75 Feet.											

Distances given are from Mains to Service Box

Wire sizes in B. & S. Gauge and Circular Mils. All conductors larger than No. 6 are stranded. Insulation, Okonite 5/32 in. wall, 1/10 in. lead

Breakdown strain 10,000 Volts A. C.

FIG. 7—TABLE OF SERVICE LATERALS

THE PRESIDENT: Mr. Barnes' paper is now open for discussion. Mr. Woodward, have you anything to say on this subject?

MR. W. C. WOODWARD (Providence, R. I.): The paper that Mr. Barnes has read has been in the hands of all the members here, and there is very little that I can add to what is published in the paper except to confirm what has been said.

There have been no faults whatsoever found in the system; even weak points which we had expected have not yet appeared, and it is true that the success of the three-wire, direct-current, 250-500-volt system has led to the introduction of the same voltage on the same arrangement with the alternating current, and up to the present time there has been quite a number of installations made on the alternating system with the three-wire grounded neutral. Although, of course, it is more unpleasant to come in contact with a 250-volt circuit than with a 50-volt circuit, yet we have had no complaint from customers, either from the point of personal injury or of fire damage. The building that Mr. Barnes mentions as having been wired with a single wire in the branch circuits was the subject of considerable discussion. The fire underwriters were not at first agreeable to accepting it. Tests have been made from time to time in this building, but there is zero potential at all times from neutral to earth, so we think we have nothing to fear from the electrolytic action. In order to make the system doubly safe, there was a neutral run as a riser, but there is no neutral copper in any of the branch circuits, it being purely a one-wire system in the branches.

MR. G. H. WHITFIELD (Richmond, Va.): Mr. Barnes mentions that some of the buildings were rewired. Did the company pay for that, or did the consumer?

MR. WOODWARD: In our first installations the company assumed the expense; in the installations being made at the present time the consumer bears the burden.

MR. P. JUNKERSFELD (Chicago): I have been much interested in the paper just read, particularly on account of the fact that there are very few of these 500-volt, three-wire plants in this country. The claims made for it are interesting and the scheme is one that from a purely engineering stand-

point has much in its favor. The commercial aspect, after investigation, is often less promising. The paper deals particularly with the investment feature of the installation. I believe it would have been a good thing if we could have heard a little more, perhaps, about the operating features of the system, particularly as regards the difference in losses in the 250-500-volt and the more common 125-250-volt systems.

With incandescent lamps there is a considerable difference in cost of lamps and in energy loss. The statement is made in the paper that they run 3.3 watts per candle, which is exceptionally good for 250 volts; but even that makes a considerable difference at the end of the year over 3.1-watt, 125-volt lamps. The arc-lamp situation is even more serious. The loss amounts to a very considerable sum in the course of a year, and this energy is a finished product, delivered at the customer's premises, and if the company can market the energy it is worth whatever their average income may be per kw-hour.

Another serious item is meter loss. Meter losses are doubled. In place of the ordinary six-watt shunt loss per meter, there are 12 watts lost due to the doubling of the voltage. The meter slip in the course of a year also amounts to a very considerable item. All of these things are offset, it is suggested, by the difference in fixed charges on the investment required. Whether or not this is true, in part or in whole, is a matter for consideration. Each individual case must be considered by itself. It depends on the area which, for commercial reasons, needs to be served with direct current, and the density of load within that area. If such area is large enough to require, say, three or more substations with a properly arranged 125-250-volt system, these substations can usually be located within the denser portions, thus making a considerable reduction in the difference in investment. The theoretical comparison in copper required tells only part of the story in the actual working out of the 125-250 and 250-500-volt systems. The greater losses in the 250-500-volt system frequently much more than offset the difference in fixed charges. Even under such circumstances, where the 250-500-volt system will apply, the straight alternating system is a serious competitor. I have no doubt that under the conditions at Providence this system is all right, but generally speak-

ing the system should be applied with a great deal of care, and unless the conditions are right and unless the future growth of the city is going to be different from that of most American cities, the time is likely to come when the lower-voltage system might prove the more advantageous.

MR. LOUIS A. FERGUSON (Chicago): I should like to ask Mr. Barnes if these arc lamps really do give satisfaction; if the customers are really as well satisfied as with the standard lamps.

MR. ALEX DOW (Detroit): I wish to ask a question that is incidental to the practice described in the paper, although not controlled by the double-voltage feature of the distribution. Mr. Barnes indicates that in at least one installation the neutral is earthed to the customer's premises. Is it his intention to earth the neutral on the customer's premises wherever permitted to do so? He describes the installation as having a copper neutral riser, but the neutral is bonded to the pipe system and the frame of the building. I should anticipate that in a town where there is a street-car system the establishing of the earths at different points of the lighting-distribution system would cause a considerable flow of street-railway return current over the neutral wires of the lighting system. That flow may be very large. Frequently, in my experience, it is sufficient to disturb the regulation, and at times it is so large as seriously to heat the conductors. A case that is constantly under my observation is that of two earths made on the neutral of a three-wire system, about 8000 feet apart from one another at points between which, during the evening peak of the street-railway load, there is a maintained difference of potential of 10 volts. In that particular instance the effect is to disturb the regulation very seriously; causing unbalancing of the three-wire system and necessitating special provision being made for balancing at the different points. It might, however, cause not merely unbalancing and disturbance to the lighting, but serious heating.

MR. WOODWARD: I will answer the last speaker first, in regard to the neutral current, and will say that the lead sheaths of all our cables are bonded together in every manhole, and in every manhole there is a ground plate which is bonded to the sheaths and to the neutral, so

that we have a continuous copper neutral and a continuous lead neutral, both of which are bonded together and to the earth; and in several years of operation we have found but one section of the city—and that was very near to a point where the railway cables cross the river—where we have had any disturbance or where our lead sheath has suffered to any extent. Tests have been made at different points in the city, and little or no current has been detected.

I will take up some of the items mentioned by a former critic on the subject, and first refer to the question of meter slip. I understand that by "slip" the gentleman meant the unaccounted-for meter current. I fail to see how there would be any more slip in a 500-volt meter than there is in a 250-volt meter. The matter of shunt current can be definitely determined, and why the meter should be any more inaccurate or give rise to any more unaccounted-for losses, I can not see. As to the question of the arc lamp—the arc-lamp situation on 104 volts, direct or alternating current, is not perfect. We all look for a better lamp. We look for a lamp that is more economical. I will confess that the lamp operated at 250 volts is not so good as one operated at 104 volts; nevertheless, it has been quite satisfactory.

With reference to the substations—when it is considered that a single substation on a 250-volt, three-wire system will cover 16 times the area that could be supplied from a substation operated at 104-208 or 125-250-volt, it would seem that the system using the higher voltage, three-wire, would be in greater favor. Taking the relative values of the alternating and direct current, when you consider all classes of motors to be supplied and all classes of lighting, I fail to see how you can serve the situation with the alternating current at all times when you surely can with the direct current. I do not know of a single central station supplying a large area, where they have variable-speed motors, that has been successfully covered by the alternating current.

MR. ARTHUR WILLIAMS: May I ask of Mr Woodward how the insurance authorities have looked upon the wiring of the Union Trust Building, without neutral on the branch circuits?

MR. DOHERTY: There is one point that I wish to have

covered. Mr. Woodward says he fails to see where a continuous slip would come in on the meter on the higher voltage. The torque on the meter is proportional to the amperage, and as you are supplying current at double voltage the slip would be twice as much on a high-pressure meter. As an example of what shunt losses may amount to, I might cite one of our alternating-current circuits at Madison, where the shunt losses amount to more than the core losses of the transformers.

Mr. P. G. Gossler (New York): I notice that in the instance given of the wiring of the Union Trust Company Building all the taps are single wire, the metal-pipe system of the building being used as a return conductor. I would ask what the practice is in those buildings that do not have metallic frames. Is the piping system relied on entirely for the return for the ground?

Mr. Woodward: By no means; but we take the piping system of an old installation and wire on that. A rewired installation, a revamped installation, would have a neutral copper as the third wire in the three-wire system and as the second wire in all branch circuits. The building cited was a new building and the wires were connected in the manner described more as an experiment than anything else.

In answer to Mr. Williams' question on the insurance point, the subject was brought up to the insurance people and was talked over with them, its various phases were considered, and it was not until we had a real heart-to-heart talk and had threshed out to their satisfaction and our own all the points brought up—it was not until that time that the system was put in operation. The insurance companies have made no adverse comments from that time to the present.

Mr. J. H. Hallberg (New York): Mr. Ferguson's question in regard to the commercial success of the twin-carbon arc lamps that are used in Providence should have further consideration. About one year ago I had the pleasure of discussing the twin-carbon, 250-volt arc-lamp situation with Mr. Barnes, who at that time was looking for an improved type of multiple arc lamp for 250-volt service. My personal impression is that the double-carbon, 250-volt, multiple arc lamp as used in Providence may prove satisfactory under certain conditions, but it is by no means a satisfactory solution of the

250-volt arc-lighting problem. I would ask Mr. Barnes if he does not find it necessary, in order to satisfy some of his customers, to use two arc lamps in series on his 250-volt circuits.

MR. WOODWARD: We have no such instance where we have two arc lamps in series; we have not done it at all.

MR. HALLBERG: Then the understanding is that the Providence company furnishes only twin-carbon lamps or the standard multiple 2.5-ampere, 250-volt arc lamp, and its customers can be satisfied by either one or the other of these lamps.

The matter is of considerable importance to operators of 250-volt plants, inasmuch as it has, as a general rule, been found necessary to use two arc lamps in series on 250 volts in order to satisfy customers. The twin-carbon, 250-volt arc lamp may give satisfaction in a case of absolute necessity, but this style of lamp is an undesirable addition to the central-station equipment, not only on account of the special care required in its adjustment, but because its successful operation after it has been properly adjusted depends upon the diameter and softness of the carbons.

The clutches in the twin-carbon arc lamps are operated by one magnet core and must lift both carbons to the same height at the same instant if satisfactory illumination is expected. It is difficult to get carbons of equal diameter and softness necessary with this form of lamp, and if one clutch should wear more than the other there will be a difference in the pick-up of the carbons and one arc will be longer than the other; which will also be the case if one carbon is smaller in diameter or softer than the other.

MR. FERGUSON: I think that if Mr. Barnes and Mr. Woodward would explain the lamp, we should better understand it. I think that many of us do not clearly understand what the lamp is.

MR. WOODWARD: There seems to be a little doubt as to what lamp was meant, but if Mr. Barnes did not make it clear I will endeavor to do so. The lamp is simply one that has four carbons; the two sets of carbons being operated in series, so that the two arcs are burning in a single inner globe. The difference of potential across each arc is approximately 75 to 80 volts, so the sum of the arc voltage is about 150 to 160 volts; that is, the lamps are used in multiple on 250 volts at about 2.3 amperes per lamp.

MR. FERGUSON: What is the difference between that lamp and two lamps in series? You say the lamps take 80 volts across the arc and there must be two in series.

MR. WOODWARD: There comes up this point: If you have a customer who desires only one arc lamp, it will be necessary to find some place to use the energy that would ordinarily be taken with the other lamp in series with the one the customer requires. You can not ask him to pay for dead current consumed in a rheostat or some device like that, so instead of having two types we have one type, and a customer wanting but one lamp is supplied with one.

MR. JUNKERSFELD: In one case you sell the customer two lamps in the same globe, and in the other case you sell one of these lamps. Where you sell the customer one lamp in this same globe, some one loses the energy that might run the other lamp. It costs the central station no more in energy to supply the double 575-watt than the single 290-watt lamp. If you are fortunate enough to have a customer to take both, you get a return for all the energy. Do I understand you correctly?

MR. WOODWARD: If you will refer to the paper you will see that the energy in each lamp is 575 watts. It would be the same if you used two lamps in series. You have the same energy in two arcs that you would have in one arc, with the single lamp. In our case we use the lesser current and use two arcs in series, whereas in the case you cited you would have about five amperes, twice the energy, and the lesser voltage.

THE PRESIDENT: As I understand it, he uses 2.3 amperes and uses it twice, and gets the same watts as if he had twice the amperage in one arc.

CAPTAIN WILLIAM BROPHY (Boston): Referring back to the Union Trust Company Building—that is an iron frame?

MR. WOODWARD: Yes, sir.

CAPTAIN BROPHY: You connect your neutrals to the frame and use the frame for one side of the taps, and connect the neutral to the conduit system inside the building? You carry two cables into the building from manholes in iron ducts?

MR. WOODWARD: Yes, sir.

CAPTAIN BROPHY: So that, so far as grounding there, it ends between the building and the last manhole. Now, have you ever had half the lights go out, so as to throw the load on to the neutral?

MR. WOODWARD: It is a three-wire system, with three cables entering the building. The point should have been made clear that the neutral was continuous from the point of supply to the point of use. It was emphatically stated that it was continuous; and by "continuous" is meant that it was metallically continuous—that is, a continuous copper, no fuse at all. It would be impossible for one side of the system to be interrupted by reason of any trouble in the neutral. The neutral is continuous at all times.

CAPTAIN BROPHY: One fuse in one side of the system might blow, and in that event your neutral would come into play?

MR. WOODWARD: If a fuse on one of the wires happened to blow, the lights would go out.

CAPTAIN BROPHY: Did that ever happen?

MR. WOODWARD: It never has happened.

CAPTAIN BROPHY: Then the only ground you have is the lead sheathing back to the station?

MR. WOODWARD: The ground is the copper conductor of the neutral, the lead sheathing of the entire cable system, and the grounded points at every manhole.

CAPTAIN BROPHY: These cables are in ducts?

MR. WOODWARD: In the streets. The service wires are in iron pipes.

CAPTAIN BROPHY: The main ducts are clay?

MR. WOODWARD: Yes, sir.

CAPTAIN BROPHY: In other buildings, where you have no iron frames, how do you ground your neutral in the building?

MR. WOODWARD: The neutral is a copper neutral in such buildings; although we advocate grounding at all possible points to the water or steam system of the building, the copper neutral is always sufficient in such cases.

CAPTAIN BROPHY: My contention is that when it is grounded on the water-pipe it is no ground at all, as the word "ground" is understood. It is connected with a mass of iron pipes capable of carrying away the current, and the potential of this pipe is increased.

MR. WOODWARD: We do not trust to the pipe system entirely; we simply make assurance doubly sure by asking them to connect to grounded points where possible; but the copper conductor in the neutral wire is always sufficient.

CAPTAIN BROPHY: In other words, in grounding any neutral wire, or the secondary of any transformer system, in order to secure any degree of success it is necessary to connect with the water system; and driving a stake in the ground and expecting to carry any amount of current through the ground is wrong—it can not be done. Grounding in the manhole is an unnecessary proceeding, as you will find that no current passes away at that point.

MR. WOODWARD: As stated in the paper, every precaution was taken, and possibly we were overcautious and did not need to put the grounds in the manhole; nevertheless, they were put there, in order to make the neutral ground as absolute as possible.

CAPTAIN BROPHY: I believe that the term "grounding the neutral," so called, is a misnomer; it is wrong to say it is grounded. But in every case it should be connected with the water-pipe in the system; otherwise it is not worth anything.

MR. WOODWARD: That is a matter of opinion.

MR. E. V. MATLACK (St. Louis): We have a system in St. Louis similar to this, except that we carry 240-480 volts. Our neutral in the underground conduits is the lead sheaths of the two-wire cables—nothing else. In the houses we carry the three wires as usual. The neutral wire is wiped on to the lead sheath of the two-wire service cable.

We have no service boxes in the manholes, the two conductors of the cables being sweated together, insulated, and covered with a lead sleeve wiped on the cable sheaths; thus making an uninterrupted neutral back to the middle of the storage battery. We have had no trouble after three years' successful operation.

THE PRESIDENT: We will close the discussion on this paper and take up the paper on "The Luminous or Flaming Arc," by Mr. Welles E. Holmes, of Newton, Massachusetts.

Mr. Holmes read the following paper:

THE LUMINOUS OR FLAMING ARC

The subject that I present for your consideration is a system of lighting by the use of a new and improved arc lamp lately brought out by the General Electric Company, of Schenectady. In this paper I shall try to interest you with a description of the lamp, the generator, and the results, not of a factory test under best and most favorable conditions, but under actual commercial conditions, as I have been operating some 30 of these lamps in connection with the plant of the Newton and Watertown Gas Light Company for about six months, the lamps having displaced 30 of the old open arcs on one of our circuits. Let me state that I think this is the first installation of the "luminous arc" lamp for strictly commercial purposes.

It is well known to you all that the design and production of electric generators has reached so high a state of efficiency as to leave little to be hoped for in the way of any marked increase along this line. We have arrived at a point where we must look elsewhere in order more economically to turn our energy generated into useful light. We have but one other place to look and that is to the lamp itself. The recognition of this is the cause of the advent of the luminous arc.

In order that you may with more satisfaction follow the details, I have had hung up here one of the luminous arc lamps. You will see that it is an open arc; that is, there is no inclosing inner globe, the exclusion of the air not being depended upon as a factor in the life of the electrodes; except for its chimney top, the general appearance is not unlike that of other arc lamps, the outer globe performing the same office as has been customary heretofore.

The lamp, nothwithstanding the fact of its being an open arc, is a long-burning lamp, the electrodes having a life of about 150 hours. In designing the lamp it early became evident that some substance or combination of substances must be used to produce an electrode of long life, low cost and good conduc-

tivity, and to the chemical research of Dr. Steinmetz, of the General Electric Company, we are indebted for the magnetite stick which forms the lower and negative electrode of this lamp. This stick, as its name implies, is made of magnetite but may be compounded with other substances to obtain a desired result. We have been from the start experimenting with differently compounded sticks, some of them being solid like a section of steel rod and others being made by inclosing powdered magnetite in a thin iron sheath. Of the relative merits of the two I should say that the filled stick, or the stick made by filling a sheath with the magnetite compound, has given the best results.

The life of these sticks has varied; purposely so, because of the fact that this six months' run has been wholly experimental. We have tried half-inch sticks and five-eighth-inch sticks. Taking the half-inch sticks we find them varying from 63 hours' to 95 hours' life. On the five-eighth-inch stick we have already obtained an average life of 182 hours with a maximum on an individual stick of 211 hours, so that it now seems possible to produce a stick with an average life of 200 hours. Just at present we are using a half-inch stick, having obtained an average life of 100 hours from it. Before leaving the subject of magnetite sticks I would say that we can be assured of the supply of this article, as it is a very common iron ore, Pennsylvania being the largest producer, followed by New York and New Jersey. The total yearly amount mined in the United States is nearly 2,000,000 tons, the average value per ton at the mines being $2.24, and the magnetite stick from the General Electric Company is to cost us $50 per thousand, or five cents for each trim.

For the upper or positive electrode we have two segments of copper. One segment, which I will call the striking segment from the fact that the arc is struck by contact with it, is made of cast copper; the other segment, made of rolled copper, I will call the burning segment, for the reason that the arc does not burn where it is struck, but the two segments change places, as it were, after the lamp is started; the reason for this change I will explain under "operation."

This positive burning electrode of rolled copper does not consume away, but, rather, is inclined to increase in weight, due to the deposit of oxide from the negative magnetite stick.

Coming now to the operation of the system we have a direct-current lamp requiring four amperes and 80 volts, and having no four-ampere, direct-current generator we cut down the current strength of a multi-circuit Brush generator from 6.8 to four by passing some of the current through a rheostat and letting the regulator do the rest. This is successfully done, but we at first tried to run the lamps on 3.4 amperes, and when cutting the generator down to this figure it made the field so weak as to be unstable for good practice, sometimes causing the generator to "die" during its run; the arc in the lamps was also unsteady at 3.4 amperes.

It seemed best, then, to use four amperes as the current strength, and the General Electric Company is now building direct-current generators of the Brush multi-circuit type and wound for four amperes in 100-125 and 150-light sizes. These machines have an efficiency of about 89 per cent and regulate one ampere either way from four. It is obvious that a generator wound for this current strength will be much more efficient than our present practice of using up the undesirable portion of the 6.8-ampere current by means of a rheostat.

The action of the lamp is as follows: When started, the pick-up magnet draws the magnetite stick up until it strikes the cast-copper or striking segment before referred to, and immediately falls away to its burning position about one inch below the copper, at the same time drawing its arc. The striking segment then draws away, the burning segment taking its place, the arc following from one segment to the other. In the action of changing segments the arc is not interrupted, as the distance between the magnetite electrode and these segments is maintained the same by reason of the segments swinging in the arc of a circle. The lamp now burns with an arc about one inch long, and a fine smoke is given off by the magnetite electrode, which smoke is taken care of by the chimney occupying the central portion of the lamp. The lower opening of this chimney is immediately over the arc, the top of the chimney being open to the air and provided with proper rain shield. On account of this smoking characteristic, the lamp may not be used for inside work unless we are sometime to be provided with a smoke-consuming device that will take care of this "bad habit."

Some of this smoke or oxide dust is deposited on the burn-

ing electrode of rolled copper in the form of a fine powder. If this dust were deposited on the striking electrode it would be liable to prevent the lamp striking its own arc again after it had started the first time. Therefore it is seen that the striking electrode, by reason of its drawing away after having struck its arc, is always maintained in a clean condition for striking the arc again, while the rolled copper or burning electrode may become covered with dust without in any way affecting the ability of the lamp to strike its arc as many times during the night as it may go out.

Just over the arc and fitting around the base of the chimney is a nickel reflector inside the globe. In our observations of the lamp, this reflector is found to add about 10 per cent to the light distributed, and on account of the arc being fixed, this small reflector gives better results than would the larger reflectors commonly used.

In treating of comparisons I use only the watts at lamp terminals. Our question now is this: Does this 320-watt luminous arc lamp give more light than any one of the following lamps?

340-watt,	6.8-ampere,	open-arc,	
460 "	6.6	"	series direct inclosed,
460 "	7.5	"	alternating inclosed.

My answer is that it does, but only by a small margin. We have determined this by the luminometer,—a simple instrument for comparing the strength of illumination at points distant from the lamp by reason of the light being thrown upon a printed card within the instrument—and find that this card with a certain sized type is readable 10 to 15 feet farther in the case of the 320-watt luminous arc than it is with any one of the other lamps mentioned.

With so small a margin of light to its credit, wherein lies, then, the advantage of this lamp? It is in the average distance at which we are able to read this card in the luminometer. Taking either of the 460-watt lamps, their maximum readable distance was 335 feet while their minimum readable distance, because of their varying arc, was about 180 feet, giving their average readable distance as 267 feet; while with the 320-watt luminous arc, the maximum readable distance was 350 feet, the

minimum 300 feet and the average 325 feet. We therefore see that the percentage of variation between maximum and mean and minimum and mean is in the luminous arc about eight per cent but in the carbon arc about 30 per cent, and the average candle-power of the 320-watt luminous arc lamp is better than that of the other lamps considered.

I have given you the amount of energy expended at lamp for a result in candle-power as above shown, the difference between 320 watts over 460 being a very appreciable saving.

You have in the case of the luminous arc an illumination of one foot per watt expended and in the carbon arc an illumination of about .53 foot per watt expended, and, further, the reduction in C_2R loss is certainly an item to be considered, for our line loss per mile, say No. 6 wire and 7.5 amperes, would be about 120 watts, while in the four-ampere circuit about 40 watts per mile, a saving of 80 watts for the luminous arc.

As to the maintenance. I think I have already stated that the magnetite sticks are to cost $50 per thousand. There is no expense for inner globes or washing same. The outer globe is the same standard article you now buy. The expense of the lamp repairs should be no more than at present, as the lamp is not delicate or complicated in its mechanism. The globe pan with its consequent shadow is something we still have to keep, but this shadow can be in a great measure eliminated by the use of a half-ground globe. We must have a perforated globe pan, as the lamp is dependent on some slight draft to carry the products of combustion up the chimney ; stopping this draft will result in coating the globe with the red oxide given off by the magnetite stick.

In conclusion, I would say that I have at Watertown, Mass., 30 of the latest type of this lamp burning every night, and Mr. Edgar, our president, wishes me to extend to you all an invitation to see them in operation.

DISCUSSION

MR. A. H. MANWARING (Philadelphia): I should like very much to ask Mr. Holmes as to the maximum and minimum voltage of the arc obtained in this form of lamp. He mentions an 80-volt arc, but does not specify whether this is the striking voltage or the feeding voltage. I would also ask if a satisfac-

tory arc can be maintained at a variation of two amperes, as it is stated that the regulation of the generator is one ampere each way from three amperes.

As to the coating of the globe, we have made some experiments with the flaming-arc lamp and we found that the globe became coated with red oxide, which we were unable to remove. Will Mr. Holmes kindly inform us as to the amount of air space necessary in the bottom of the globe in order to avoid the coating mentioned?

MR. HOLMES: The voltage at the arc, so far as our measurements go, is shown to be 80, with very little variation. As to the question of the regulation of the Brush machine, my statement on that may be misleading; it was not meant that the machine would not regulate except one ampere either way from four. That was the range of the machine. The regulation of the machine can be kept at four amperes or be varied so as to go up to five or varied so as to go back to three; so that you can burn the lamp on three, four, or five amperes. That is not a characteristic of the machine—not this particular machine; the machine will not vary in its regulation that much when set for four amperes.

As to the dust or coating on the globe—the holes in the globes that we first used were on the side, so when the wind blew through the holes it caused the copper dust to collect on the globe. From our experience we concluded that the lamp needed a strictly upward draft, and in our next globes we had the globe opening indented and holes drilled in the indented portion so that the side wind could not be blown into the globe pan but must come up from the bottom, and that has remedied the difficulty that we at first experienced through the coating of the globe with the red oxide.

MR. M. E. TURNER (Cleveland): I ask Mr. Holmes in what direction the maximum is from the horizontal, and if in making the comparison with the other arc lamps the heights of the lamp above the ground were taken into consideration, so as to make a proper comparison?

MR. HOLMES: The heights of the lamp were taken as we found them to average over a large number of tests. I can not give the exact height of the different lamps, but they were taken as we found them in the municipalities in and about New-

ton and Boston. The maximum direction was horizontal, and the light has been the nearest approach to sunlight of any arc lamp that we have had.

A MEMBER: I ask how the globe and the light, as regards color, have been affected by the different experiments on the magnetite composition? That is, although Mr. Holmes' last remark perhaps touched upon that—the light at present being the nearest approach to sunlight in the arc lamp—I want to know to what extent that quality is variable in the composition of the magnetite stick.

MR. HOLMES: That effect is dependent upon the composition of the magnetite stick. Those of you who were at the convention of the Association of Edison Companies at the Thousand Islands saw Dr. Steinmetz vary the color of the magnetite sticks by different compositions. It is possible to vary the color of the rays of light in this lamp by different compounds in the composition of the stick. The General Electric Company is experimenting in this direction so as to give us a stick that will come as near to producing daylight as is possible.

MR. JOHN F. DUSMAN (Baltimore): Mr. Holmes has told us that we must have a certain shaped pan to the globe. Could not that be done away with?

MR. HOLMES: We have not tried the inclosed-bottom globe. It might be done away with by the use of the inclosed-bottom globe if you have the ventilation. But there are hot particles from the magnetite which might have a bad effect on the inclosed-bottom globe.

A MEMBER: To what extent is the lamp affected on very windy nights, as compared with calm nights? The pan being perforated, necessarily, in order to give an upward draft, to what extent is that draft affected on very windy, stormy nights; particularly windy nights?

MR. HOLMES: With the globe pan we now have we have no trouble in that way, the difference between a windy and a calm night not being noticeable to us. Before we had the present globe pan we were troubled by the lamp kicking a great deal, caused by the draft making the arc unsteady and cutting out.

MR. S. G. RHODES (New York): I ask if Mr. Holmes anticipates any trouble from corrosion or oxidation from the

metallic fumes given off by the magnetite on the mechanism of the lamp.

MR. HOLMES: The chimney goes through the entire lamp. The mechanism of the lamp is not exposed at all to the fumes of the magnetite or copper—not in any way; the fumes go straight up through the chimney and go out through the chimney top.

MR. H. T. HARTMAN (Philadelphia): Will the lamp stand a rise of six or seven amperes temporarily?

MR. HOLMES: The lamp will stand six amperes easily and safely. The effect of the flash will be to make the lamp kick.

MR. DAVIS: Does not the long arc make the light flicker?

MR. HOLMES: It is perfectly steady a little way off. If you come up near to it you can liken it to a stream of water. You can see, although the passage of the current is downward, that it has the appearance of going up, due to the heat evolved in the arc passing out and enveloping the arc in going up the chimney.

MR. J. W. GILLETTE (Phoenixville, Pa.): As to the consumption of the electrode?

MR. HOLMES: There is no consumption of the upper electrode; nothing, as I have shown to you. That electrode that you see has been in contact with the electric current—has been burning—six months and shows little or no deterioration. The magnetite stick burns away, as I have stated here in the paper, and has different lengths of life.

MR. JOHN F. GILCHRIST (Chicago): I ask if the lamps that Mr. Holmes used commercially have been for street-lighting purposes or for store lighting—that is, outside of stores; and, if so, how the customers are impressed with them.

MR. HOLMES: We have used them for municipal purposes only—for street lighting. We have no lamps in a store or underneath the porch of a store; they are all on the street.

THE PRESIDENT: What does the public think of them?

MR. HOLMES: It is very much pleased with them. They think in Watertown that they are the finest lights they have ever seen.

A MEMBER: What is the variation of the lamp between the starting temperature and after the lamp heats up? Some of our long-burning arc lamps increase in voltage so as to cut down the capacity of the arc machines after the lamps are

heated. How much does this lamp vary in voltage due to heating?

MR. HOLMES: I have no particular figures on that point. The only knowledge I have is that the lamp is fairly cool, due to the upward draft; there is no heating of the mechanism in the top part of the lamp. I have nothing positive on that particular point, however.

MR. HALLBERG: Will Mr. Holmes please state if he has experienced any trouble from the sputtering of the metal or lower electrode on the outer globe? It seems as if in the course of time it would be necessary to replace globes on this account, and a roughening or blistering of the glass globe would make it difficult to clean.

MR. HOLMES: We have not had time in the six months that the lamps have been burning to get any data on that point. There has been nothing serious of that kind developed, whatever; what may come, I can not say.

MR. H. W. HILLMAN (Schenectady): In regard to the attitude of public opinion toward this lamp, I will say that the electric-light company in the city of Jackson had the opportunity to secure another contract, and it was familiar with the trial of this system at Newton. Representatives of the company came on to see the light. They were well pleased with it, and they felt that they could secure a contract with this new system. They later sent on the entire common council and the mayor. They went over to Newton. They did not give any notice of their coming, so the system was not fixed up in as good shape as it might have been, and they took it as it was that night. They went back to the lighting company at Jackson and closed a contract for ten years for 300-light capacity. The material will all have been shipped in a few days—by June first. They did not want to take up the contract on the basis of watts energy consumed in the lamps, and the Jackson people showed them how to use the luminometer for testing the illumination of lamps at a distance on the street. It was conceded that a sufficient amount of illumination was given underneath the lamp for almost any purpose; it was a question of illumination at a distance about which they desired to be satisfied. Now, in the inclosed-arc system that has been heretofore installed, the best 6.6-ampere series direct-current inclosed arc or the best 7.5-

ampere series alternating-current inclosed arc has a distance illumination equivalent to about 257 feet for reading a certain line on the card inside the luminometer. The Jackson-people closed the contract on the basis of 225 feet distance, knowing that they could get an average illumination of 300 feet either side of the lamp. So much for public opinion.

There is just one other point with regard to the energy that was standardized, so to speak; it was rather difficult to know for just what current we should build the system. Assuming that you should use 6.6 amperes at 80 volts, or 480 watts, the same as the inclosed arc is now operated, there would be a tremendous amount of illumination; something that has not been heard of for street illumination—almost like a miniature searchlight, only you would get the light on four sides and would not require an attendant to change it about. It did not seem wise to adopt that high energy, but, rather, to take the standard illumination as it is to-day, and after getting a little bit better illumination at a distance, due to the light efficiency of the lamp and its ability to throw the light at the horizontal, we determined to take 300 watts and give the central station the benefit of the difference.

The President: We shall have to close the discussion. We have on this morning's programme the reports of four committees, all of whom are going to ask to be discharged, and I think possibly it would be well to adjourn this until the beginning of the afternoon session. It will not take more than five minutes to discharge the four committees, as they request.

(On motion, adjourned until half after two in the afternoon.)

SECOND SESSION

The meeting was called to order by President Edgar promptly at half after two o'clock.

REPORT OF COMMITTEE ON UNIFORM ACCOUNTING

THE PRESIDENT: We will now take up the consideration of the four committee reports that were left over from the morning session. We will first consider the committee on uniform accounting, of which Mr. Guy L. Tripp, of Boston, is chairman. Mr. Tripp wrote me a letter saying that he regretted he could not be present at this meeting and that he had nothing further to report as chairman of the committee.

MR. W. M. ANTHONY (Chicago): I move that the committee on uniform accounting be discharged.

(The motion was carried.)

REPORT OF COMMITTEE ON LEGISLATIVE POLICY

THE PRESIDENT: The committee on legislative policy is another of these committees. Mr. Samuel Insull, of Chicago, the chairman of the committee, is abroad. The committee has done no work for several years, and the chair will entertain a motion that the committee be discharged.

MR. ANTHONY: I move that the committee be discharged.

(The motion was carried.)

THE PRESIDENT: The committee on standard candle-power of incandescent lamps, Dr. Louis Bell, chairman, and the committee on photometric values of arc lamps, Mr. Henry L. Doherty, Denver, chairman, are the two remaining committees to be considered, but as the chairmen of these committees are not in the meeting-room, although present at the convention, we will pass them for the present.

We will now take up the paper "A One-Hundred-Mile Transmission Line," by Mr. Robert Howes, of Spokane, Washington.

Mr. Howes read the following paper:

A ONE-HUNDRED MILE TRANSMISSION LINE

In the following it is not the purpose to indulge in long explanations, descriptions, or theories, but rather to give a brief description of the essential features of the plant, the results obtained and difficulties encountered.

The observations recorded are to be considered as reasonably accurate, but, as you all know, observations in an operating plant have to be made when one has the opportunity, and usually just at the time when he would like to be taking interesting readings, he is so busy with operating features that there is little time to make accurate notes.

The plant considered is that of the Washington Water Power Company, of Spokane, Washington. The power-house is located at the foot of the lower falls of the Spokane River, in the very centre of the city of Spokane. The theoretical head on the water-wheels is about 71 feet.

That portion of the plant which furnishes the power for the transmission line is composed of two Y-connected, 4000-volt, 2250-kw, 60-cycle, 300-r.p.m., revolving-field alternators, each direct-driven from a pair of forty and one-half-inch special turbines, made by the Stillwell-Bierce and Smith Vaile Company, and designed to develop 4000 horse-power under 68 feet of effective head. The water is supplied to each unit through a steel flume 10 feet in diameter and over 500 feet long.

The wheels are governed by Lombard governors, with compensating action modified to meet the demands occasioned by kinetic energy of the water moving in the long flumes. These governors can be relied upon to keep the speed from rising or falling over three per cent from the normal with instantaneous changes of 600 kilowatts at any position of the gates, and will care for small changes of load to within one-third of one per cent of normal speed.

The accompanying diagram gives the important electrical connections. All instruments have been omitted, to avoid confusion of lines, but a fairly complete set is installed. Each generator is supplied with voltmeters, ampere-meters and watt-meters in each leg, and the leads to the step-up transformers also

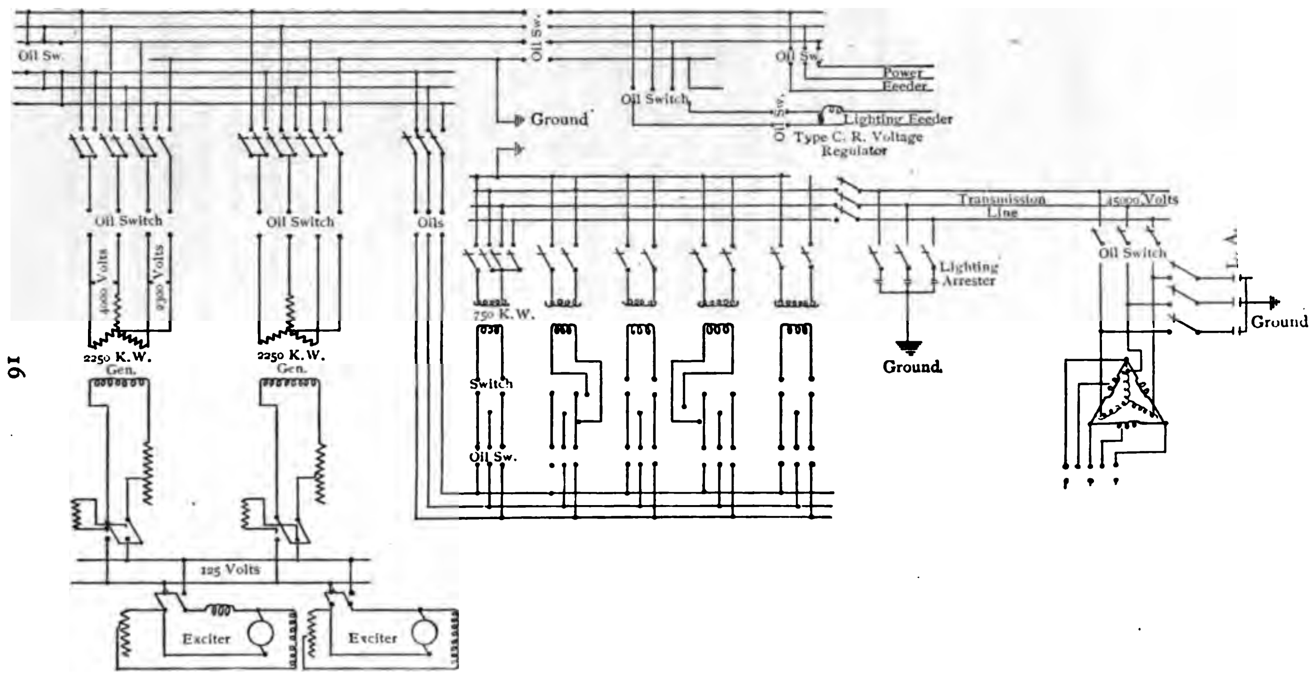

Diagram of Electrical Connections for 100-Mile Transmission Line

have ampere-meters and a power-factor indicator. By running one of the generators alone on the transmission line a complete set of voltmeters, wattmeters, ampere-meters and power-factor indicator is available. All the electrical apparatus is of General Electric Company's make, the indicating instrument being of the horizontal edgewise type.

The principal exciter is driven from a separate wheel, which is supplied with water from either of the two flumes. An induction motor, not yet in operation, is to be connected to the end of the exciter shaft, opposite the water-wheel, and driven from the transmission leads inside the oil circuit-breakers. It will serve the double purpose of governor and insurance against lack of power for the exciter if the chute-case of the water-wheel becomes partially choked up. An indicating wattmeter on the induction motor will indicate the choking of the water-wheel by showing that the motor takes more load. The exciter will then be started and the choked wheel cleaned out.

The plant is designed to furnish three-phase current at 4000 volts for local power and 2300-volt, single-phase current for local lighting service in Spokane. Any lighting feeder can be thrown on either of the three legs of the Y-connected generator, by means of the type "G" oil switches, and the load on the generators kept balanced. Type "C. R." hand voltage regulators are installed on the neutral or grounded side of each lighting feeder; the voltage being regulated with the aid of a voltmeter compensated for the line loss.

The generator, transmission line and main city switches are motor-controlled and of the type "H" variety. Those on the transmission line and city have automatic overload tripping devices. The city feeders have automatic oil circuit-breaker switches, hand-operated.

The step-up transformers are 750-kw each and of the water-cooled type. They are connected in delta on the 4000-volt side, and in Y on the high-tension side, the neutral connection being grounded at the power-house. The high-tension winding is for 34,700 volts, taps being brought out for 26,000 volts also, thus giving a choice of 60,000 or 45,000 volts line pressure. Two spare transformers are installed, and the switching arrangement is such that one of the spare ones can be cut in to replace either of the three in use without shutting down. The second spare one

can be connected on any phase by shutting down about one minute.

Three banks of lightning arresters are installed on the line; one at Spokane, one at the end of the line and one about 20 miles from the end of the line.

The main line is 98 miles long at the farthest substation and has three short branches at present. Low-tension current is transmitted about two miles farther up the cañon, making the total transmission just 100 miles.

On leaving the power-house, the line goes through the city streets for three and one-half miles; the poles used being from 40 to 85 feet long, in order to get above everything that might be interfered with. Wherever it crosses other lines, grounded wires are strung over them several feet below the transmission line.

Leaving the city, the line follows a county road for about 24.5 miles, till it reaches the Cœur d'Alene Indian reservation. Across this, a distance of 24.8 miles, almost all in heavy timber, a private right of way was obtained and cleared of all trees and brush. All trees outside the right of way, liable in falling to reach the line, were also felled. At one point in this portion, the line crosses the St. Joseph River, where it empties into the Cœur d'Alene Lake. The river runs close to a bluff on the west, while on the east side there is a marsh and the neck of an inlet. At high water several feet of water stands from bluff to bluff. To span this would require a span of 3300 feet, so resort was had to setting the poles on a cluster of five piles. The centre one being driven about six feet lower than the others, a socket was formed in which the pole was firmly clamped with heavy iron bands. By this means the longest span was reduced to 474 feet across the river channel, the wires being far above the smoke-stacks of the steamers that navigate the river. Number 0 B. & S. hard-drawn copper wire was used here for further security against a wire breaking. A row of single piles with a plank walk was placed across the marsh under the line, for patrolling purposes. Thus far this construction has proved most satisfactory.

Leaving the reservation, the line follows up the valley of the Cœur d'Alene River and the south fork of the same to the mining region. It is largely on private right of way, but follows county roads in part, and goes through a mixture of

swamps and meadows—sometimes several feet under water—timber-covered mountains, steep rocky mountain sides and around rocky cliffs. As far as possible it was considered best to avoid proximity to towns, railroad tracks, etc., where the youth with a 22-calibre rifle likes to walk and practice shooting, for the insulators offer a tempting target to those of a mischievous nature.

The poles of the present line are set 35 feet from the north or westerly side of the 100-foot right of way, leaving room for a duplicate line on the other side.

The standard pole is 35 feet long, of winter-cut cedar, 12 inches at the ground line and 8 inches at the top. They are set six feet in the ground. Special lengths are used in hollows at bottoms of ravines, etc., to avoid making too great a change in the slope of the wires on any one insulator, also at railroad crossings and in villages.

The wires are of No. 2 B. & S. medium hard-drawn copper, and are placed to form an equilateral triangle 42 inches on a side. The upper insulator is set on the top of the pole, the others at either end of the cross-arm. A complete set of three partial transpositions is made in each section where the condition varies in paralleling telegraph, telephone lines, etc.; otherwise in every mile.

A private telephone line is run on the side of the poles below the power line and is transposed every few spans. The insulators used are of the double-petticoat type, 13-inch size, and are mounted on a metal pin. This pin is described by Mr. D. L. Huntington in the Transactions of the American Institute of Electrical Engineers for April, 1903, page 453, and has given entire satisfaction to date.

The substation buildings are of brick. The high-tension wires, entering near the top, go directly to knife-disconnecting switches, set on a gallery, thence to the transformers on the ground floor. One transformer of the three-phase type is used. The secondaries pass from a transformer to a switchboard, carrying oil circuit-breakers, recording wattmeters, and indicating instruments, thence to the customers' circuits. The half-voltage taps shown on the diagram are for starting purposes only, for synchronous motors. There are eight of these substations, six of which have been in continuous use since starting. Besides the above, there is a substation recently built about 11 miles from

Spokane, where power is taken from the transmission line and the voltage stepped down to 23,000 to supply the lines of an interurban railway 33 miles long. The railway company uses the power through rotaries to supply the trolley with 600-volt direct current.

Several miles of long-distance telephone line parallels the transmission line at a distance of about 40 feet, and one of the telephone company's engineers was much worried, fearing trouble with the operation of these lines. Three days after the transmission was in operation, he asked when the current would be turned on, as he wished to notice how much the change was. Upon learning that the current was on, he admitted he could not detect it in the operation of the telephones. There is very little sound on the private telephone line from induction unless one wire becomes grounded, when it becomes almost impossible to understand a person at the other end.

A rather peculiar loss of from one to six feet of head in the draft tubes is encountered at ordinary height of the river. The centre of shaft is then about 18 feet above tail-water. Not far above the intake to the power-house the river divides into several channels, and falls over numerous small dams and cascades (composing the "upper falls") about 60 feet, reaching this level a few hundred feet above the intake. There being no quiet water whatever, considerable quantities of air seem to be taken into the flumes with the water, and no doubt are held there under pressure as the water flows down the flumes, to be instantly released upon passing through the wheels into the partial vacuum. This, no doubt, explains a part of the loss of head.

Another peculiar phenomenon is noticed every time one of the 4000-hp wheels is started, of which the writer has found no satisfactory explanation, and would be glad to hear one. The following characteristic observations were recorded by him: The pressure at centre of shaft, according to gauge, being noted as 24 pounds and the vacuum in draft tubes being zero, the gate of the wheel was opened slowly. Full speed was reached in about one minute, the gate being nine per cent opened. The vacuum was noted as rising rapidly. The speed remained steady for two or three minutes and the vacuum increased to 10 inches of mercury; suddenly the wheel slowed down 20 per cent, the vacuum continuing to rise to about 13 inches of mercury, where it

remained practically stationary. The wheel continued to run at steady speed and 20 per cent low until the gate was further opened, it requiring 16 per cent gate opening to bring the wheel back to speed. The pressure gauge showed a loss not to exceed one-tenth of a pound, while the vacuum remained about the same.

The power-house being ready before the line was completed, 77 miles of line was first tested. All switches were closed and the generators started slowly from rest. The speed was gradually increased, the connections having been made for 60,000 volts pressure. The pressure was brought up to 42,000 volts and then cut down slowly to zero without any indications of trouble.

Next morning the machine was started again in the same manner, the voltage being raised to about 68,000 volts for a short time, and then lowered to about 58,000 or 60,000 volts, and held there all day while the entire line was patrolled and found to be in good condition. Along the line a discharge could be heard at a large percentage of the insulators. With 58,000 volts on the line, the amperes shown on the generator were 230 in each leg, while the wattmeter indicated 25 kilowatts per leg. This would show the charging current to be approximately 15 amperes, while, after the step-up transformer loss was deducted, the remaining energy lost in the line would not be over 10 kilowatts per wire, or a total of less than 30 kilowatts. In this test only one set of lightning arresters was connected, they being at Spokane; each division of the set was composed of 24 General Electric 2000-volt, double-pole arresters connected in series, thus forming 96 spark-gaps from each wire to ground. A steady stream of sparks could be noticed through the first few air-gaps. These became less frequent as the number of gaps crossed became greater, and before reaching half-way down the arresters the sparks were no longer visible. The leading current exerted such an exciting effect on the generator that the exciter voltage had to be reduced to 85 volts and all the generator fields resistance cut in, giving an exciting current of about 50 amperes, whereas, with the generator half-loaded with non-inductive load, the exciter was run at 115 volts with the generator rheostat handle in about central position.

After this test the line was shut down for four days, the transformers were connected for 45,000 volts line pressure, and

the first substation, 79 miles from Spokane, cut in. The voltage was brought up to 43,000 volts, and simultaneous volt readings were taken by means of telephone, the voltage being very steady. The voltage indicated at the substation was a little over 44,000. The voltmeters were new, but were not compared; however, the error should not have been two per cent. The amperemeters in Spokane on the 4000-volt side of the transformers indicated 120 amperes, giving about 10.5 amperes for charging current at this voltage, there having been two more miles of line cut in and also an unloaded transformer and bank of lightning arresters at the substation since the test at 58,000 volts.

During the first test the neutral wire was not grounded at the power-house, and the floating around of the neutral point was plainly noticed on the lightning arresters, the sets connected to the three wires showing considerable difference, sometimes one being most active and then another. Grounding the neutral wire stopped the greater part of this effect, although a slight varying difference still seemed to exist.

As induction motors were started, the amperes supplied to the step-up transformers decreased until a minimum reading of about 95 amperes was reached. The kilowatts were not observed, owing to the generator furnishing current to the city as well at this time, and the proportion of the total supplied to each could not be accurately obtained. After this time, adding more load increased the current, accordingly the minimum current is about eight and one-third amperes for 79 miles of the line at 43,000 volts.

The work was rapidly pushed to completion and the substations were put in operation, each substation being put into service as soon as the line reached it. The power was cut off only long enough to make connections to each piece of new line. Accordingly, no opportunity to test the charging current and the kilowatts of the complete line was had; for one could never be sure that all the load was off at the various substations. From two of these current is supplied for lighting purposes, the towns of Wardner and Kellogg being lighted from one.

At the time of writing, unity power factor is usually reached with a load of 1450 kilowatts. The current in the line is then about 18.5 amperes per mile. Four 300-hp induction motors, one 240-hp synchronous motor, and several induction motors of

smaller sizes, are in operation on the line. One of the 300-hp induction motors is supplied from the substation at the end of the line, and is direct-connected to a hoist which is almost in constant use. During the first two months this had to be run entirely unbalanced. The effect of this hoist upon the regulation of the line was at first very serious. The motor is a three-phase General Electric, built for 514 r.p.m., 2080 volts and 60 cycles. When the load on the line was light and this motor was started, it would throw a heavy inductive current on the line, increasing the power factor instantly, leaving the generator much under-excited, and causing the voltage to drop accordingly. To this had to be added a drop of about one or one and a half per cent, due to drop in speed. The speed would be just about recovered when the load would come off again, restoring the power factor and excitation to the generator, while the speed would rise about as much as it fell on starting the motor, causing the voltage to go slightly above normal. Ordinarily, the voltage at Spokane would fall about 10 or 12 per cent and rise two per cent from normal, while extreme cases were nearly twice as bad. The voltage at the end of the line would in general vary about 1.6 times as much as it did at the power-house. This action continuing every two or three minutes, needless to say, made the power unsatisfactory for lighting purposes, while the speed variation of the induction motors was enough to bring forth severe complaint where they were used to run milling machinery requiring a very constant speed. Even the synchronous motor, judging from the attendant's account, would start to fall out of step, slip over a few poles, and again get in step, but causing much anxiety. After a day or two of this, a man was put in constant attendance on the generator rheostat, and the writer went to the end of the line to study conditions and see what could be done. He found that the motor as then handled took about 275 kilovolt amperes for the first point on the controller. The operator would then move the handle rapidly, bringing the kilovolt amperes up to 400 or 450, make the run and shut off quickly. The time of raising the car from the 300-foot level was 25 seconds, and from the 600-foot level was 45 seconds. It was noted by comparing recording voltmeter charts that the attendant at the switchboard in Spokane could do little to keep the voltage from falling, but would bring it back very quickly.

When the motor was cut out the voltage would rise nearly as much as it had dropped before. However, the general effect was much improved. It was found that the controlling rheostat of the motor was too small to stand regulating the speed of the motor for any considerable time, so, as a temporary makeshift, a resistance was made of iron wire and inserted in the circuit between the starting box and the rotor. This had the effect of cutting down the kilovolt amperes taken at the first point to about 175, and the operator could then move the controller handle more slowly. The first instantaneous drop in voltage was much reduced, and the attendant at the power-house had a chance to hold the voltage nearer normal. With this condition the voltage would usually fall at the power-house about six or seven per cent and would rise nearly as much above normal. While this gave pretty poor lighting service, it did not seriously interfere with the motors. This arrangement, however, has the bad feature of running the motor at a slower speed and so doing only the work of a smaller motor. This is not serious while operating from shallow shafts, but would be unsatisfactory for deeper workings, which will be worked in the future. Accordingly, the writer recommends for such requirements a rheostat large enough not to overheat when running with any part of it in use, the first point to give a current nearly as small as that taken by the motor with the rotor open-circuited. The second point would increase the current about 30 per cent, the next 30 more, the remaining ones to give more gradual changes. The motor would not start until the third, or if heavily loaded, perhaps the fifth, point. The controller handle should also have a time relay device, making it necessary to consume about three seconds between the first and second points, two between the second and third, and one for the next, also a smaller time limit for cutting out these points. An emergency switch should be provided, so that the operator could cut off the current instantly, if necessary. This would enable the power-house to care for the small changes and keep the voltage near its standard there, the line loss being the principal thing left to contend with.

A large water rheostat was installed at Spokane and used in connection with the transmission line, and was found to be of use on light loads; but when the power factor reached 100 per cent it did little good and could be cut out. It was hoped that a volt-

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age regulator ordered would be installed in time to record the results herewith, but at time of writing the regulator had not arrived.

A suggestion made, but not tried as yet, is to install a large synchronous motor at the end of the line, with no load except its own exciter, and install one of these regulators to operate on the field of this motor. If the line voltage dropped, the regulator should strengthen the motor field and throw a leading current on the line. If the voltage rose, the field should be weakened to throw a lagging current on the line. The objection to using a motor installed for other purposes is that the motor would often be shut down, and would be largely out of the power company's control.

It may be of interest to note that while the line has been in continuous operation for over seven months, the circuit-breaker has been tripped only eight times, excepting when arrangement for a short shut-down has been made with all parties interested. Of these eight times, two were caused by accidental short-circuits on the line, made by the company's workmen; four were short-circuits on the secondaries of customers, and were severe enough to throw out the secondary breaker, the substation breaker and the power-house breaker all at once; the other two were from unknown causes. The total time the power has been off because of these troubles is 32 minutes.

DISCUSSION

MR. HOWES: Since I wrote this paper we have received the voltage regulator, and we had it installed in time for me to know the results before I left Spokane. We succeeded in holding our voltage at Spokane practically steady. There was a variation not to exceed three-fourths of a volt above or below the normal on a 116-volt basis. At the other end of the line this cut down the variation to a trifle over one-half of what we had before. Then the controller for the motor arrived, but without a time-relay device. When that was installed we cut down the variation at the other end to one-half of what it was then, leaving us with a variation at the other end of the line of about one-fourth of what it was when I wrote this paper. We have now total variations of five to six per cent at the end of the line in extreme cases. I have copies of some voltage charts

that I made just before leaving Spokane, and shall be glad to show them to any member who is interested in the work.

THE PRESIDENT: Mr. Howes' paper is now before you. If there is no discussion on this paper the chair will proceed to the next paper.

MR. R. S. KELSCH (Montreal): I ask how many times it has been necessary to shut down this high-tension transmission line to make repairs, or any other changes, in addition to the seven times in the eight months that have been referred to?

MR. HOWES: The power has never been cut off for repairs except to cut in the substations. We made the most of the opportunity while cutting in these seven substations. Each time we shut down we renewed any damaged insulators, chiefly caused by boys throwing stones or shooting small-calibre rifles at them. They were contemplating arranging for a short shut-down as I was leaving, to change some temporary connections and replace damaged insulators, and it has probably been made by this time, but we have not made any solely for repairs.

MR. GOSSLER: I notice on page 93 that you refer to having three banks of lightning arresters, one at the end of the line, one at Spokane, and one about 20 miles from the end of the line. Have you had any lightning storms since the line has been in operation, and, if so, what was the effect on the line; also what was the amount of power being transmitted at the time of the storms?

MR. HOWES: A few days before I left there was quite a severe storm. We never have such severe storms as in the East or in the middle states, but we have had a number of ordinary storms without any effect whatever. The last storm punctured the insulation on a current transformer for operating the high-tension circuit-breaker in a substation and caused a shut-down of about 20 minutes. A day or two afterward a shut-down of over an hour was caused by a road supervisor putting several sticks of dynamite under the stump of a tree and blowing it through the wires. It twisted the wires all together, but we had the power on again in a little over an hour. These are the only two instances of serious line trouble that we have met with.

DR. LOUIS BELL (Boston): Mr. Howes' experience with that big induction motor at the end of the line is one that should be borne in mind by every one running a big transmission system, for this reason: For some reason—perhaps a psychological one—which is inexplicable to me, people ask or expect that in-

duction motors shall show a degree of immunity from troubles produced on the line, and other ills that motors are heir to, that is quite different from anything we have been led to expect or to which we have been accustomed with continuous-current motors. A big motor of that kind is bound to make trouble unless the starting rheostat is laid out with the idea of avoiding trouble. If it is laid out on merely general principles, as a rheostat might, could, or should, be laid out, if then the motor is going to some unknown place and is put on the end of a 100-mile transmission line, it is almost certain that there will be constant trouble from it, for the simple reason that the lower steps of the starting rheostats are not, in three cases out of four, made with the fine gradations necessary.

Mr. Howes has found it necessary to make an emergency regulator for just that purpose, so that in every case in dealing with the induction motor at the end of a long line, particularly a big motor (and all big motors are slow-speed motors, in which the power factor is liable to be low at times), it must be a matter of prime necessity to get at the design of the rheostat and lay it out with intelligence and care, as in the case of a continuous-current motor of the same rating. Under these circumstances, relatively little trouble will be experienced from these big motors.

Corresponding to the conditions of regulation imposed by that unfortunate rheostat, comes the question of the power factor of the circuit; and it is worth while calling attention to the fact that unity power factor is a point where the system gets a bit hypersensitive. I believe one can do better by running a little under unity power factor all the time, never giving the current a chance to cross and become a leading current. We can, by working at power-factor unity, get oscillatory factors in both directions, with magnetizing and demagnetizing action on the generator coming in quick succession in response to changes in load. The big induction motors are known to have a considerable steadying property, and if this steadying property is so utilized as never, except for the moment of starting on an empty line, to pass to a negative power factor, so to speak, and thus pass on to a leading current, the chances of oscillatory shifts of voltage will be in great measure obliterated.

MR. W. L. ABBOTT (Chicago): I think the success of the Spokane company with its line has been very good, considering the experience the Commonwealth Electric Company has had

with its only overhead, 9000-volt, three-phase, 25-cycle line, which is about nine miles long. Where this line runs in the city we have had trouble as often as once a month, due to malicious mischief. It was put out of business once by lightning and twice by boys with hay-baling wire, and in one case with a trace chain ; again, by some one who needed the copper. In a recent instance, about ten days ago, a boy who knew how to make a Fourth of July demonstration threw a chain over the lines and burned two of them off. One of the wires, in falling, struck him on the shoulder and burned him severely.

THE PRESIDENT : Before proceeding to the next paper we will go back to the reports of committees that were left over from the session of this morning. We will take up the report of the committee on standard candle-power of incandescent lamps, Dr. Louis Bell, chairman.

REPORT OF COMMITTEE ON STANDARD CANDLE-POWER OF INCANDESCENT LAMPS

DR. BELL : Your committee on the standard rating of incandescent lamps has only a brief verbal report to make before asking to be discharged. The commercial conditions of incandescent lighting have remained fairly stable during the past year ; that is, primary standard lamps are now available from more than one concern, and in general the conditions regarding standardization of lamps have taken a very quiet course, so that it is hardly necessary to comment on that at length or to make any extended report. I feel that the work of the committee was pretty much accomplished when the time came that standard lamps could be obtained and a general understanding was reached as to what would be desirable in the matter of rating and measuring lamps.

This being done, your committee asks to be discharged. But in closing I should like to make one recommendation, and that is that in cases of reports of this really technical character a closer co-operation of the members of the association is necessary. The members can do a great deal more for each other, working through a committee, than the committee itself can do for any of them, and the suggestion that your committee has to make is that in cases where work of this kind is to be undertaken a proper method of doing it would be to send out to all the members of the association a searching circular, asking for detailed statements of conditions as they find them, and that

the answers to these circulars be digested and passed out as a confidential document so that every member of the association might know what the other members are doing and their opinions on all important points. At a subsequent convention a special or general committee, or some one in charge of the matter, could take hold of the valuable data thus obtained and make a report with which every one who had participated in gathering material for it would feel familiar and could discuss to the best advantage. This is a suggestion thrown out to facilitate the handling of these technical questions.

Your committee asks to be discharged.

MR. ANTHONY: I move that the committee be discharged.

(The motion was carried.)

THE PRESIDENT: We will now consider Mr. Eastman's paper, entitled "The Advisability and Methods of Grounding the Neutral on High-Potential Alternating-Current Generators."

An abstract of the following paper was read by Mr. George N. Eastman, of Chicago:

THE ADVISABILITY AND METHODS OF GROUNDING THE NEUTRAL ON HIGH-POTENTIAL ALTERNATING-CURRENT GENERATORS

It is the principal object of this paper to present a few conditions that will arise on any alternating-current system, resulting in a production of dangerous potentials relative to earth, and to show that these conditions will arise only on a system that is insulated from the earth. The conditions and problems presented, when carefully considered, will, I believe, show that any advantages that may be obtained by operating a system insulated from earth will be more than offset by the liability of obtaining high potentials relative to the earth, as herein described.

The relative potentials between any part of a high-potential alternating-current system and ground will be governed by the distribution of the electrostatic capacity of the line conductors and the apparatus connected thereto. In general, the insulation resistance to ground will have practically no influence on the relative ground potentials. This will be readily seen by comparing the insulation resistance of an ordinary circuit with its reactance of condensance; for example: The insulation resistance of a circuit one mile in length, consisting of two No. 0000 conductors, placed 12 inches apart in air, would normally exceed 500 megohms. The condensance between the conductors with 60 cycles would be approximately 160,000 ohms. In a No. 0000 paper-insulated, 10,000-volt, lead-covered cable, the insulation resistance between any conductor and the lead should exceed 500 megohms. The condensance between a conductor and lead will be approximately 14,000 ohms.

Any condition that will arise on a high-potential alternating-current system, which is insulated from earth, disturbing the relation of electrostatic capacities in any part of the system, will affect the ground potentials throughout the entire system. This can be best shown by considering the problems that will arise in a particular installation. For this purpose, I have

chosen a four-wire, three-phase system and will describe some conditions the consideration of which has led the engineer of the Chicago Edison Company and the Commonwealth Electric Company to ground permanently the neutral of all their high-potential alternating-current generators.

In December, 1900, the Commonwealth Electric Company of Chicago completed a new power station in which were installed one 500-kw and one 1000-kw star-wound, 60-cycle, three-phase, alternating-current generators, designed to operate at a star-potential of 2300 volts or 3980 volts between phases.

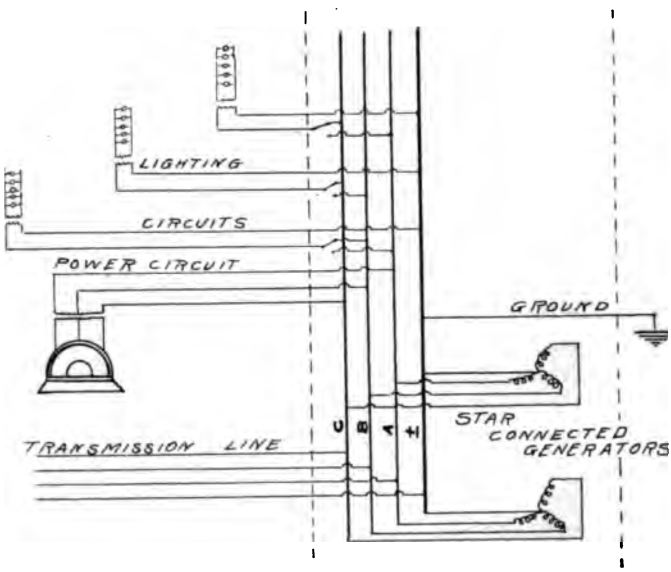


FIG. 1

The switchboard was so arranged that the distributing-circuits could be operated all in multiple on one four-wire 'bus with parallel operation of generators, or divided between two 'busses with the generators operating independently. The distributing system consisted of 350 miles of overhead conductor and 14.5 miles of underground cable, the greater part of which had previously been operated as single-phase circuits at a potential of 2000 volts. These circuits were rearranged and subdivided into two-wire, single-phase lighting circuits, three-

wire, three-phase power circuits, and two four-wire, three-phase transmission lines, connecting the generating station to a distributing substation. A diagram of system, showing parallel operation of generators, is given in Figure 1.

Since the three-wire circuits have no neutral and the four-wire transmission lines have but one neutral conductor for the three-phase conductors, the total length of line conductors connected to the neutral 'bus was less than the total length of line conductors connected to the phase 'busses. Of the 364.5 miles of circuit conductors, 158 miles of overhead lines and six miles of

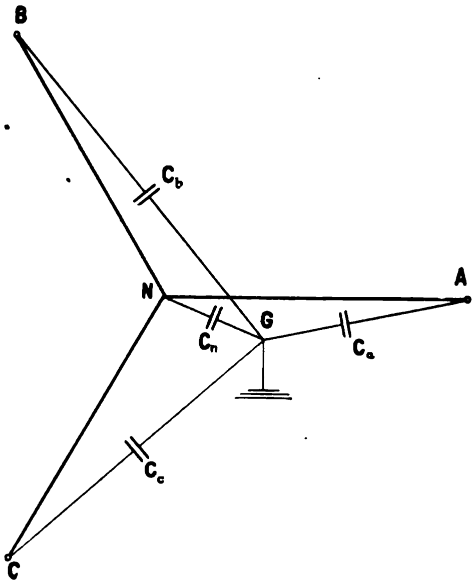


FIG. 2

underground cable were connected to the neutral 'bus, the remaining 192 miles of overhead lines and 8.5 miles of underground cable being distributed between the phase 'busses.

As shown in Figure 1, the lighting circuits are so arranged that they may be operated between the neutral and either of two phase 'busses ; this arrangement being made for the purpose of distributing the lighting load equally between the three phases of the generators.

It is obvious that in this system the number of miles of circuit conductors connected to each of the three phase 'busses

will depend on the length and load of the lighting circuits. The chances, therefore, of obtaining an equal length of circuit conductors on each phase 'bus would be very remote. Assuming that this condition were obtained, there would be connected to each phase 'bus 64 miles of overhead and 2.8 miles of underground conductor. This condition would represent a system in which the electrostatic capacities are balanced. The condensance of the entire system between neutral and ground would be 4.3 microfarads. The condensance between each phase and ground would be 2.2 microfarads. This condition is represented

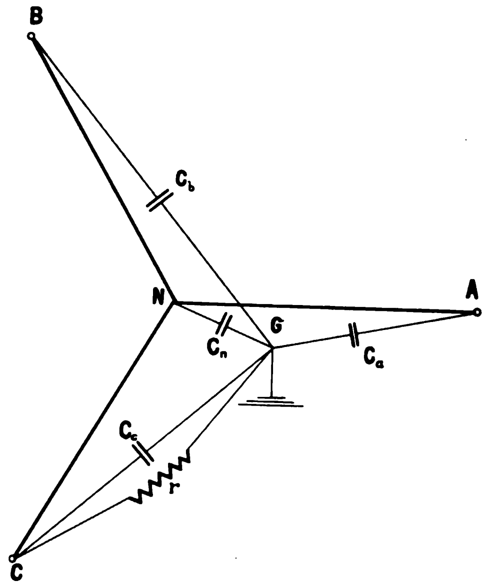


FIG. 3

diagrammatically by Figure 2. *ABCN* represents the star diagram of pressure; the condensance between phase conductors and ground being represented by *Ca*, *Cb* and *Cc* and the condensance between the neutral and ground being represented by *Cn*.

With 60 cycles, the reactance of each phase condenser, which connects the phase to ground, will be 1700 ohms. The reactance of the neutral condenser, which connects the neutral to ground, will be 900 ohms. It is obvious that with this condition the voltage impressed on each phase condenser will be the

same, and so long as the system is free from ground no potential will exist between the neutral of system and ground. Should one phase conductor become grounded in any manner, the relative potentials between the system and ground will be changed.

An equation was derived in the following manner to determine the relative potential that will exist between the neutral of the system and ground when one phase becomes grounded through a purely ohmic resistance.

Substituting values for the reactance of condensance, in Figure 3, let *Ca*, *Cb*, *Cc* and *Cn* represent the reactance of condensers *Ca*, *Cb*, *Cc* and *Cn*, respectively, and *r* represent the ohmic resistance through which the *C* phase is grounded.

Let *Ia*, *Ib*, *Ic* and *In* represent the current that will flow through the condensers *Ca*, *Cb*, *Cc* and *Cn*, respectively, and *Ir* the current that will flow through the resistance *r*.

Since the sum of all the currents meeting at a mesh point is *o*, then

$$Ia + Ib + Ic + In + Ir = o \tag{1}$$

From Figure 3
$$Ia = \frac{GA}{j\,Ca} = \frac{GN + NA}{j\,Ca} \tag{2}$$

$$Ib = \frac{GB}{j\,Cb} = \frac{GN + NB}{j\,Cb} \tag{3}$$

$$Ic = \frac{GC}{j\,Cc} = \frac{GN + NC}{j\,Cc} \tag{4}$$

$$In = \frac{GN}{j\,Cn} \tag{5}$$

$$Ir = \frac{GC}{r} = \frac{GN + NC}{r} \tag{6}$$

Substituting current values in (1) and solving, when star pressure=2300 volts.

$$NG = \frac{r\,Cn\,[2300\;Cb\;Cc - 1150\;Ca\;Cb - 1150\;Ca\;Cc] + 1992\;Ca\;Cb\;Cc\;Cn - j\,Cn\,[1150\;Ca\;Cb\;Cc + r\,(1992\;Ca\;Cb - 1992\;Ca\;Cc)]}{r\;Cn\;Cb\;Cc + Cn\;Ca\;Cb + Cn\;Ca\;Cc + Ca\;Cb\;Cc + j\;Cn\;Ca\;Cb\;Cc} \tag{7}$$

When $Ca = Cb = Cc$

$$\text{then } NG = \frac{1992 - j\,1150}{r\,\frac{3}{Cc} + \frac{1}{Cn} + j1} \tag{8}$$

From equation 8 an expression can be obtained for the tangent of the angle *ANG*. It is easier, however, to substitute numerical values in equation 8 and lay the angle off graphically, than to solve for the tangent of the angle.

In equation 8, taking for the values of *Ca*, *Cb*, *Cc* and *Cn* the value of reactance considered, the pressures to ground have been determined for values of r, varying from infinity to o.

When $r = inf.$	$NG = 0$	$AG = 2300$	$BG = 2300$	$CG = 2300$
When $r = 2000$	$NG_1 = 394$	$AG_1 = 2020$	$BG_1 = 2675$	$CG_1 = 2265$
When $r = 500$	$NG_2 = 1315$	$AG_2 = 2115$	$BG_2 = 3610$	$CG_2 = 1885$
When $r = 125$	$NG_3 = 2165$	$AG_3 = 3450$	$BG_3 = 4190$	$CG_3 = 755$
When $r = 0$	$NG = 2300$	$AG = 3980$	$BG = 3980$	$CG = 0$

This condition can be represented diagrammatically as shown in Figure 4. Referring to figure, with C grounded through a resistance of 500 ohms, the ground will be located at the point G_2 on diagram, and so long as the grounding resistance does not change the system will operate with the relative

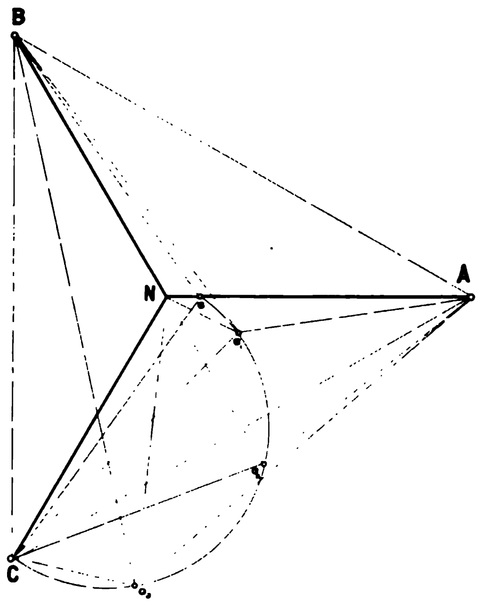


FIG. 4

potentials to ground given in the above table. It will be noted that with a resistance of 125 ohms, the potential between B phase and ground is 4190 volts, which exceeds the delta pressure of the system.

Diagram Figure 5 represents a condition that may be obtained where the ground is of an inductive character. Let

N, *A*, *B* and *C* represent the 'bus-bars of the four-wire, three-phase system. One circuit is shown connected between the 'bus-bars *N* and *A*. The capacity of the neutral conductor of this circuit is represented by the condenser *Cd*. The capacity of the rest of the system is represented by the condensers *Cn*, *Ca*, *Cb* and *Cc*. In case the neutral wire of the circuit should become disconnected from the 'bus-bar, the phase *A* will be grounded through the primary of the transformer *T* in series with the condenser *Cd*. Should the neutral of the circuit be-

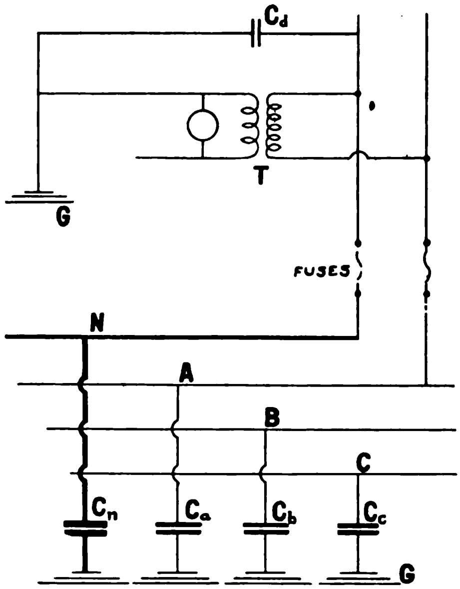


FIG. 5

come grounded and disconnected from the neutral of the system, the phase *A* would be grounded direct through the primary of the transformer *T*. This is but one example of the many conditions by which the system would become grounded through an inductive reactance.

The following equation was derived for the purpose of determining the potentials that will exist when a phase conductor of the system becomes grounded through an inductive reactance, as represented in Figure 6. The reactance of each phase condenser being the same, it is represented by x. The reactance of the neutral condenser is represented by y. The

ohmic component of the grounding reactance is represented by r, and the inductive component is represented by w.

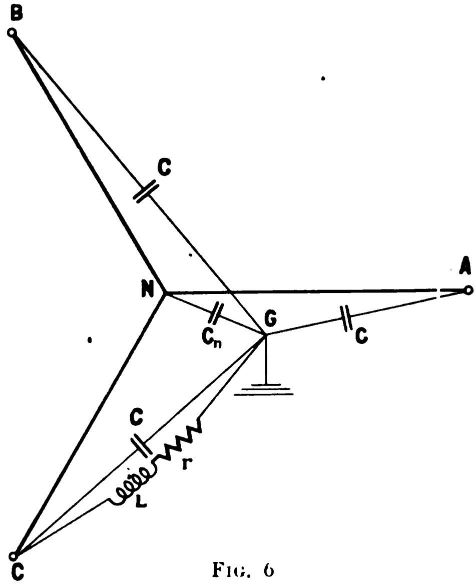


FIG. 6

Let I_a represent the current in A phase condenser, I_b the current in B phase condenser, I_c the current in C phase condenser, I_n the current in the condenser C_n, and I_r the current in rL.

$$I_a = \frac{GA}{jx} = \frac{GN + NA}{jx} \tag{9}$$

$$I_b = \frac{GB}{jx} = \frac{GN + NB}{jx} \tag{10}$$

$$I_c = \frac{GC}{jx} = \frac{GN + NC}{jx} \tag{11}$$

$$I_n = \frac{GN}{jy} \tag{12}$$

$$I_r = \frac{GN + NC}{r - jw} \tag{13}$$

$$I_a + I_b + I_c + I_n + I_r = o \tag{14}$$

Substituting the current values in 1 and solving

$$GN = NC \cdot \frac{xy}{w\,(3y + x) - xy + jr\,(3y + x)} \tag{15}$$

Substituting for GN its vector value,— $a - jb$ where $a = 1150$ and $b = 1992$

$$GN = \frac{-xy\,(a + jb)}{w\,(3y + x) - xy + jr\,(3y + x)} \tag{16}$$

$$\text{and Tan. } ANG = \frac{(bw - ar)\,(3y + x) - b\,xy}{(aw + br)\,(3y + x) - a\,xy} \tag{17}$$

Substituting in equation 16 the value of 1700 ohms for x, and the value of 900 ohms for y, and assuming the resistance in series with the inductive reactance as zero; when w is equal to

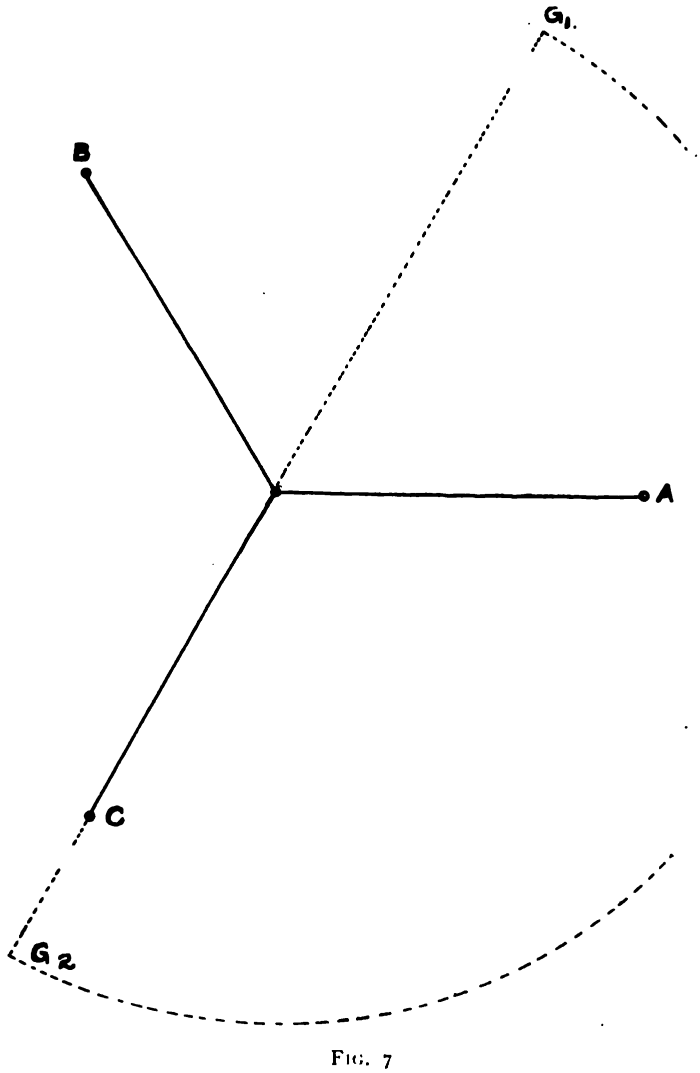


FIG. 7

infinity, the potential between neutral and ground is zero: when w has a reactance of 348 ohms, the potential between neutral and ground is infinity, and when w has a reactance of

8

zero ohms, the potential between neutral and ground is 2300 volts, which is the *Y* pressure of the system.

This condition is represented diagrammatically in Figure 7. As the reactance is varied from infinity to 348 ohms, the potential between neutral and ground travels along the line CG_1 to infinity. As the reactance is further decreased to zero, the potential decreases from infinity along the line G_1C until the point *C* is reached. This is purely a theoretical case, it being impossible to obtain an inductive reactance that will not have an ohmic component; but its consideration is of value in showing what influence the inductive component of a ground has in determining the relative potentials between the system and ground.

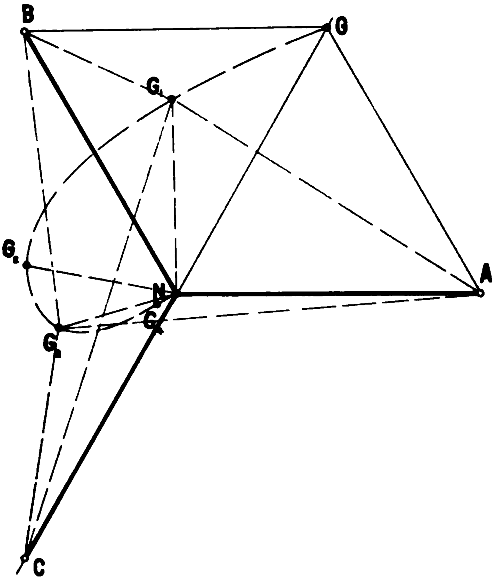


Fig. 8

Figure 6 represents a condition of a ground through an ohmic resistance in series with an inductive reactance. If we fix the inductive reactance at a value of 695.5 ohms and vary the value of resistance from zero to infinity, it will be found that the ground potential will follow the curve shown in Figure 8. With *r* equal to zero, the potential between neutral and ground will be 2300 volts, and the ground will be located at point *G* in

diagram; with r equal to 200 ohms, the potential between neutral and ground will be 1386 volts, and the ground will be located at G_1 in diagram; with r equal to infinity, there will be no voltage between neutral and ground.

All the foregoing examples apply to the system when the electrostatic capacities are balanced. As previously stated, the chances of obtaining such a condition are very remote. The relative potentials that will exist between the system and ground can be obtained from equation 7 for any arrangement of the electrostatic capacities. For example, consider the circuits are so arranged that in Figure 2 the reactance of $Ca =$ 1150 ohms, $Cb =$ 2270 ohms, $Cc =$ 2270 ohms, and $Cn =$ 900 ohms.

Substituting in equation 7 it will be found that for this condition the difference of potential between the neutral and ground will be 345 volts. Substituting in equation 7 the values of r previously considered,

When $r =$ *inf.*	$NG = 345$	$AG = 1955$	$BG = 2395$	$CG = 2395$
When $r = 2000$	$NG_1 = 710$	$AG_1 = 1690$	$BG_1 = 2915$	$CG_1 = 2460$
When $r = 500$	$NG_2 = 1570$	$AG_2 = 2030$	$BG_2 = 3870$	$CG_2 = 2050$
When $r = 125$	$NG_3 = 2200$	$AG_3 = 3350$	$BG_3 = 4270$	$CG_3 = 960$
When $r = 0$	$NG = 2300$	$AG = 3980$	$BG = 3980$	$CG = 0$

Figure 9 represents this condition and shows the manner in which the potentials vary when r is varied from infinity to o.

This one example is sufficient to show the manner in which a ground will affect a system when the electrostatic capacities of the system are not balanced. The results obtained by an inductive ground on the system can be inferred by comparing the effects produced by an ohmic ground under the two conditions considered.

It will readily be seen that grounding the neutral 'bus will eliminate the chances of obtaining high potentials between the system and ground as described in the foregoing examples. In case of a solid grounded neutral 'bus any ground on the phase conductor will either be burned off or the circuit will be cut off from the system by means of the fuses or circuit-breakers in the station.

When this system was first put in operation a switch was installed on the conductor leading from the 'bus-bar to the ground plate. In order to test for the potential between neutral and ground, this switch was opened and several incandescent lamps were connected in series across the switch. The potential between the neutral 'bus and ground when the switch was

opened was approximately 200 volts, but this potential would vary whenever a lighting circuit was thrown over to another phase 'bus. Sufficient lamps were connected to withstand a potential of 1500 volts without burning out, and the system was allowed to operate in this manner free from ground, with the exception of these lamps. During a sleet storm, the evening following the installation of the lamps, the lamps were suddenly burned out, and simultaneously with this occurrence a discharge was noted on the lightning arrester installed in the station. The following morning a five-kw lighting trans-

FIG. 9

former was discovered to be burned out, which showed indications of having been subjected to a destructive high potential. The neutral fuse of the circuit had been blown, and the primary fuse block of the transformer had been destroyed. After this case of trouble, the neutral 'bus-bars of the system were permanently grounded, and the system has been operated in this manner ever since. No case of trouble has yet been obtained on the system, with the exception of lightning discharges, in which high-potential discharges to ground have been noted.

The conditions that have been considered in the examples shown all refer to a four-wire, three-phase system. Similar results will be obtained in the consideration of any three-phase, three-wire system or of any alternating-current polyphase or single-phase system that is operated free from ground. The consideration of the conditions that have been described led to the grounding of the neutral of the generators on the 9000-volt, three-phase, 25-cycle system of the Chicago Edison Company. Since the ground has been placed on the generators but one case of trouble has developed in which there appears to have been excessive potentials on the system relative to ground. In investigating this case of trouble it developed that the neutral ground on the generators had been opened the day previous and that the trouble had occurred when the system was operating free from ground.

The principal objection that has been raised to the grounding of high-potential alternating-current generators, is that when a ground is obtained on any phase conductor a heavy short-circuit current will flow, which will be liable to cause resonance, resulting in a high-potential strain on the system. I have shown that a system could be operated continuously with a ground on one phase and have cited examples from which the current through the ground could be calculated if the reactance is known. In any system operating multiple-conductor underground cable, it is obvious that should a ground be obtained on one conductor in the cable, the ground current would be sufficient to destroy the insulation between the conductors, resulting in establishing a short-circuit between the phases of the system, which would be as disastrous as a heavy short-circuit between one conductor and ground.

It has also been suggested that a resistance be connected between the neutral of the generators and ground, which would limit the flow of current produced by a ground on the system. This would also have the effect of transferring the short from between phase and neutral to a short between phases.

I believe that the proper manner of grounding the neutral of the generators is through as low a ground resistance as can possibly be obtained; in this manner fixing the maximum potential that can be obtained between the system and ground at the normal potential that will exist between the neutral of the generator and its phase terminal. The best indorsement of grounding in this manner is the success that has been met with

by the Chicago Edison Company and the Commonwealth Electric Company in operating their system grounded.

These systems have been operated for a period of four years, during which time the systems have apparently been entirely free from the high-potential breakdowns that have been met with by other systems of a similar character that were operated free from ground. No elaborate static discharge devices have been installed, and whenever a ground was obtained upon a circuit that was not equipped with a time-limit device the circuit has been opened successfully and the operation of the system has not been affected.

DISCUSSION

THE PRESIDENT: Mr. Eastman's paper is open for discussion.

MR. HALLBERG: It may be of interest to this association to know that the Cincinnati Gas and Electric Company has operated during the past four years a system similar to that described by Mr. Eastman, and I have had an opportunity to observe its performance during the past year. The success of the system is unquestioned, and from a practical point of view it is by far the most simple and reliable system for large plants, and the regulation seems to be everything that could be hoped for. The Cincinnati company has had practically no trouble from lightning, the neutral, if anything, protecting the system from lightning discharges. I recommend, however, that when the primary neutral is grounded the neutral of all three-wire and one side of all two-wire secondaries be grounded near the transformer.

THE PRESIDENT: Is there any further discussion on this paper? If not, we will proceed to the next paper, "The Organization and Equipment of an Arc-Lamp Department," by Mr. Samuel G. Rhodes, of New York.

Mr. Rhodes read the following paper:

THE ORGANIZATION AND EQUIPMENT OF AN ARC-LAMP DEPARTMENT

The organization and equipment of a separate department exclusively for the care and maintenance of the arc-lighting service becomes necessary where the number of arc lamps is large. The service is best maintained at the highest standard when the work is specialized, and the interests of both the consumer and the company are best served by such an organization. In considering this subject, the experience and data will be drawn from the arc-lamp installation of the New York Edison company. The arc-lamp service supplied by this company at the present time represents a total of 19,300 arc lamps of the following types and classes of service:

COMMERCIAL LIGHTING

14,035 direct-current multiple inclosed lamps
641 alternating-current multiple inclosed lamps
225 direct-current series open lamps

CITY LIGHTING

1,116 alternating-current series inclosed lamps
775 direct-current series open lamps
2,400 direct-current multiple inclosed lamps
426 25-cp incandescent lamps

Of this number, 5400 are furnished under wholesale contracts, covering supply of current only, and are trimmed by the customer, who in addition furnishes all renewals and makes all repairs.

The area within which these 19,300 lamps are installed is 38 square miles, of which 1740 lamps within an area of 18 square miles are located in the Borough of the Bronx, and 17,560 lamps within an area of 17 square miles in the Borough of Manhattan, the total area of the latter being 20 square miles.

In order to facilitate the canvassing for new customers, and the extension of the field of arc lighting, the contract department has included in its organization an Arc Lighting Engineer. Under his direct supervision is the acquisition of

new arc-lighting business, the retention of existing installations, and the general care of the commercial business connected with this branch of the company's service. To him is referred prospective arc-lamp business out of the ordinary, and in many instances, in addition to being the contract agent of the New York Edison company, he acts, as it were, in the capacity of engineer for the customer. His services cost the customer nothing, and it is intended that he shall endeavor to secure for the customer the best results for the least expenditure. His assistance may be of special importance where the customer has found that his business does not warrant the illumination provided and desires a rearrangement of his installation. The competition with other forms of illumination, as, for instance, the Humphreys gas-arc lamp and the Kitson oil burner, has provided a field for work of this character, the success of which is best attested by the increase in the arc-lamp business of the New York Edison company, an increase of 32 per cent for the year ending March 31, 1904, over the previous year. Part of this new business can be fairly considered a natural increase in this class of service, but the greater part was added to the company's mains in substitution for other forms of high-candle-power lamps, as a result of the inferior maintenance that seems to be the rule in illuminants that aim to compete with arc lamps. Arc lamps of good design require but little care to give thoroughly satisfactory service, but when the aggregate number of lamps is large, and is scattered over a considerable area, this care becomes a matter of closely followed detail in order that the highest standard be maintained.

When the current is introduced in the consumer's premises, the arc-lamp department is advised of this connection, the form of contract the customer is operating under, and any other detail that should be in its records to enable the department to keep in close touch with the customer. The installation is at once inspected by the foreman trimmer, the requirements of the service are noted and the customer is added to the route of the trimmer in whose territory the installation is located.

In maintaining the character of the service, and the upkeep of the apparatus—of each particular installation regardless of its size, requirements or location—it has been found to be unwise to rely entirely on the trimmer, be he ever so careful a workman and conscientious an employee. Some form of tabu-

lated reports and records should be provided for the inspections and supervision of this work, and while it is essential that all systems of providing records be complete and in detail, they should be of the simplest character. The card-filing system is used as far as possible, and the following card contains about all the record that will be found necessary.

No explanation is necessary except, possibly, to add that the cards are filed according to avenues and streets, and that when the consumer ceases to be a customer the card is placed among the disconnected installations. Reference is possible at

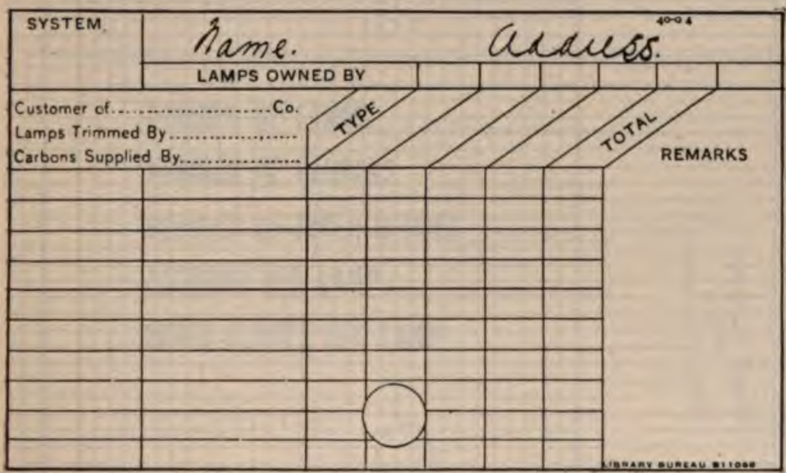
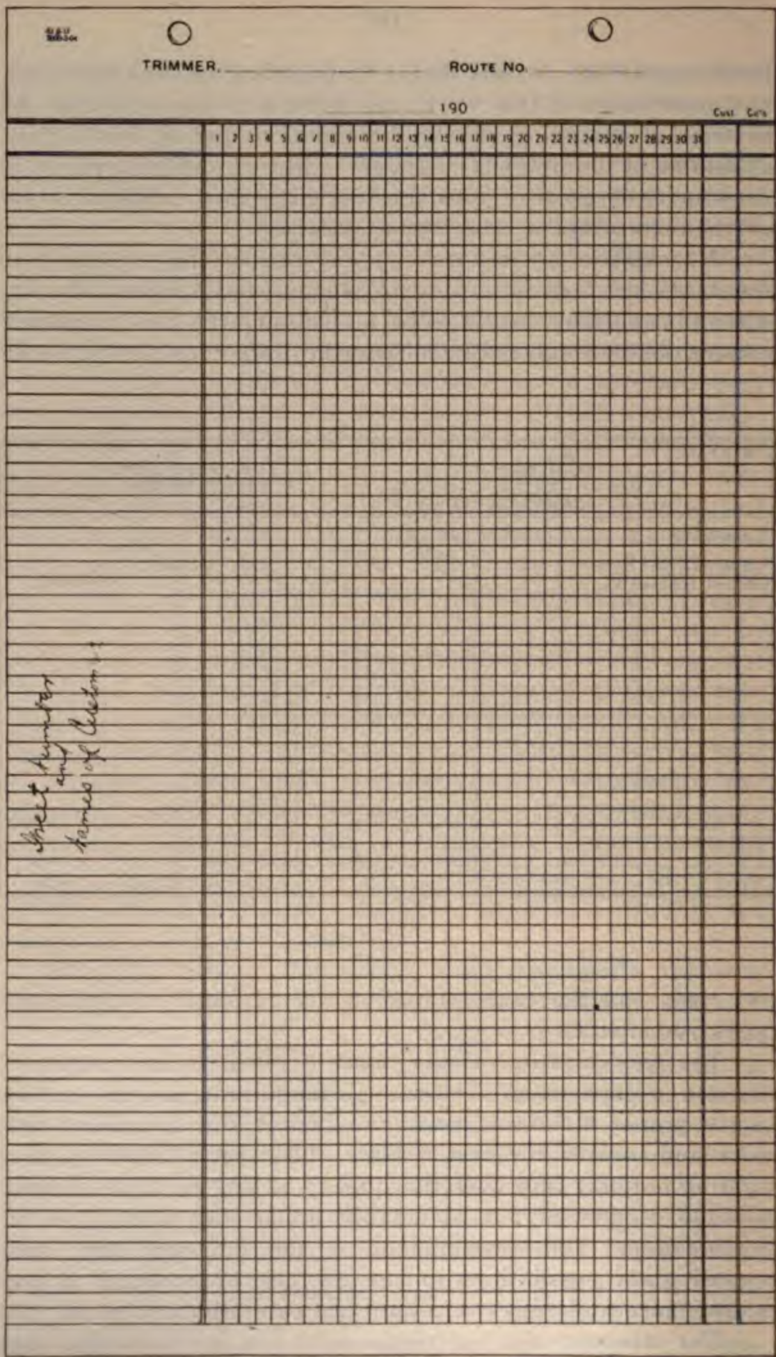


FIG. 1

any time, and the exact status of the customer's installation quickly available.

The concentration of one class of business in a separate division or department, if of enough magnitude, not only tends to the proper maintainance of the service, but specializes the work and insures the best results. The specialization of arc lighting not only improves the quality of the work but makes possible economies not obtainable under any other form of organization. The development of the inclosed lamp has opened great possibilities in the exercise of economy if the maintenance and repair accounts are carefully scrutinized.

The trimmer who is responsible for a route with an


TRIMMER, ______________ ROUTE NO. __________

__________ 190__

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Cust	Cu'n
Sheet number and names of Customers																																	

FIG. 2—TRIMMER'S ROUTE SHEET

average of 650 lamps, and of as many as 25 different types, must, of necessity, be a better workman than the old open-arc lamp trimmer. With him rests, besides the regularity of the service, the fulfillment of the foreman's ideas on proper maintenance. While a trimmer may be classed as an unskilled workman, time expended in specially training him for his work is time well spent. Careful and constant coaching will in a short time give him a knowledge of the many little kinks and expedients to be made use of to insure the best utilization of the carbons, and the highest quality of service.

For the trimmer's guidance, and so that he can arrange

NUMBER OF LAMPS............................

NUMBER OF CARBONS.......................

NUMBER OF INNER GLOBES.............

CARBONS PER LAMP.....................

INNER GLOBES PER LAMP...............

Fig. 3

his route for each succeeding day, a form of trimmer's route sheet is used as shown in Figure 2.

This sheet also provides a ready reference as to the number of carbons used by any one customer, from month to month, and is a check upon the number of lamps trimmed and inspected. The total number of carbons used is readily obtainable and can be checked with the number furnished the trimmer daily by the supply department. This form also provides a method of accurately determining the number of inner and outer globes used by the trimmer per lamp per month. These various records are necessary to secure eco-

THE NEW YORK EDISON COMPANY,

Contract and Inspection Department. **55 Duane Street, New York.)**

Memorandum on Installation Changes.

To the General Inspector:— **Date.** ____________

____________ **Customer at** ____________

for ____ **Inc Lamps,** ____ **Arc,** ____ **Type,** ____ **Amp.,** ____ **H. P. is { making / considering } the following changes**

For example:—	____________
To Welsbach,	____________
To Kitson or other oil or air burners,	____________
To Steam or Gas Engine or other power,	____________
To Private Electrical Plant,	____________
From Incandescent to Arc, or reverse,	

The following complaints are made:— ____________

For example:—	____________
Poor service (a) pressure,	____________
" " (b) apparatus,	____________
Excessive cost,	____________
Lack of attention,	

(Signed). ____________

Referred to ____________ **for investigation and report,** ____________ **(Date).**

Report. ____________

____

____________ **(Signed),** ____________

Action taken, ____________

____

File ____________ **(date)** ____________ **General Inspector.**

FIG. 4

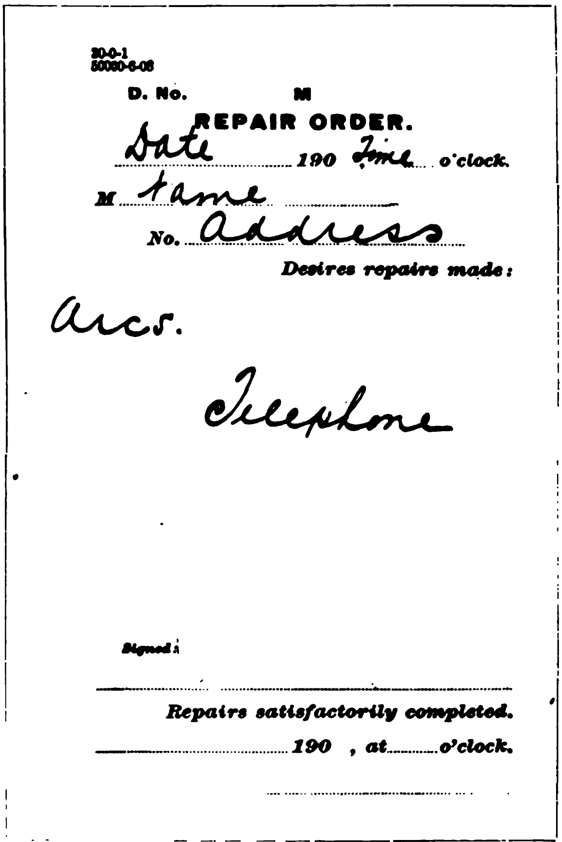
nomical operation and are all of a character that the trimmers can easily understand. A comparison, posted each month, of the trimmers' accounts, is far more eloquent than a sermon (see Figure 3).

This scheme of comparisons is likely to result in maintaining the lamps on the route in better condition, as a lamp in good repair requires fewer renewals of inner and outer globes and carbons.

Before the supplies required for the trimming of the lamps are furnished to the trimmer, they have been first compared with the specifications under which they were ordered. This comparison is made by the supply department, subject to the instructions of the arc-lamp foreman and before the material is put into stock. This precaution insures the delivery of carbons within the gauge limits, inner globes of the correct dimensions and squarely ground edges, and outer globes of uniformity as to size, shape, and, if of alabaster, of color also. A useful report turned in by the trimmer is that covering a change or contemplated change in the system of illumination. The "memorandum" shown is filled out by the foreman and forwarded to the lighting engineer. It has been our experience that other forms of illumination are usually installed temporarily on trial, and prompt attention to the report of the foreman often eliminates the suggestion of considering anything but arc lighting.

It is also made an evidence of good service on the part of the trimmer to receive no criticism of his work from the customer. This, in itself, would be impracticable without the co-operation of the trimmers and the repair branch of the department. The co-operation of the trimmer and the repair man is insisted upon and the routine is planned so that this co-operation is made easy. Each commercial trimmer personally O. Ks. his route at the close of the day to the foreman in charge of commercial lamps and reports to him in detail any trouble that the customer may have complained of, or any request made for information he may have received. The importance of these reports can not be overestimated, as they are a direct expression of opinion from the customer, and if of criticism can be acted on at once and the cause of complaint removed. Every request of the customer, made either through the trimmer, another employee, or through other channels, is made part of the departmental records.

The following form of repair slip is used, and in addition to the signature of the customer acknowledging the completion of satisfactory repairs, a check is provided as to the time consumed in making the repairs. This in itself is an important factor in securing service of the highest character. The usefulness of these slips is not yet exhausted, as reference to the reverse side



30-0-1
50000-6-06

D. No. M

REPAIR ORDER.

Date 190 Time o'clock.

M Name

No. Address

Desires repairs made:

Arcs.

Telephone

Signed:

Repairs satisfactorily completed.

190 , at o'clock.

FIG. 5—FACE OF REPAIR ORDER

will show the "trouble" and its remedy. The slips are filed in envelopes of about the same size and arranged in cabinets. The foreman does this filing, and he can thus keep in close touch with the condition of each individual installation by referring to the slips already in the envelope. The highest point of efficiency is possible, as the requirements of each installation are made a

matter of record; any shortcomings are clearly shown by the contents of the envelopes, and steps can be taken to eliminate any particular cause for dissatisfaction.

The repairs to the customers' installation are also under the jurisdiction of the foreman of the trimmers. As most of the repair calls are of a minor importance, taking but little

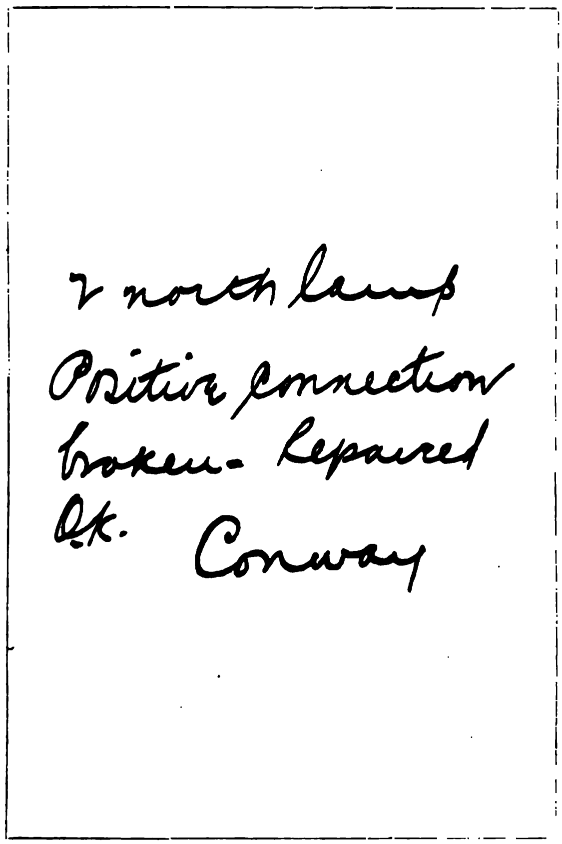

2 north lamp
Positive connection
broken - Repaired
O.K. Conway

FIG. 6—BACK OF REPAIR ORDER

time to remedy, the most efficient way is to have the repairmen report to the district headquarters and there receive and attend to repair calls. These repairmen are expert wiremen, having a good working knowledge of the various types of apparatus connected to the company's mains, and in

addition have been given a course of instruction in the arc-lamp repair shops. It has been the practice to keep these men posted by giving them bench work for two weeks at a time. When a repairman completes his day's work he files, on a separate report, the arc-lamp repairs he has made dur-

Fig. 7—Carbon Cutter and Punch for Cutting Washers

ing the day, and what disposition he made of them. In this way, one expert arc-lamp mechanic on the following day can inspect and repair the lamps on the entire system that require repairs to their mechanism. One man will make repairs of this character that ten repairmen turn over to him. This method is a positive check on the character of

the work of the repairman as well as the trimmer, and confines extensive repairs, outside the repair shop, to one man.

Should the lamp require changing, the adjustment-room is called on for a new or readjusted lamp. The entire stock of arc lamps is carried in one place—a scheme that has been found to decrease the amount of surplus stock. The arc-lamp shops are equipped to repair and readjust lamps of all types and systems, the various types of current required

FIG. 8—INNER-GLOBE WASHING MACHINE

being available. The work is under the supervision of a working foreman, who is responsible for all the lamps that are tested and for their operation after leaving the adjusting-room. It has been found that one man is required for each 600 open lamps, while one man can readily look after the shop repairs necessary to an installation of 2000 inclosed lamps. But few records are required in the shop, and those

of purely a departmental character. Arrangements are made for keeping the repair costs of the different types of lamps, by whom repaired, the number of lamps repaired weekly,

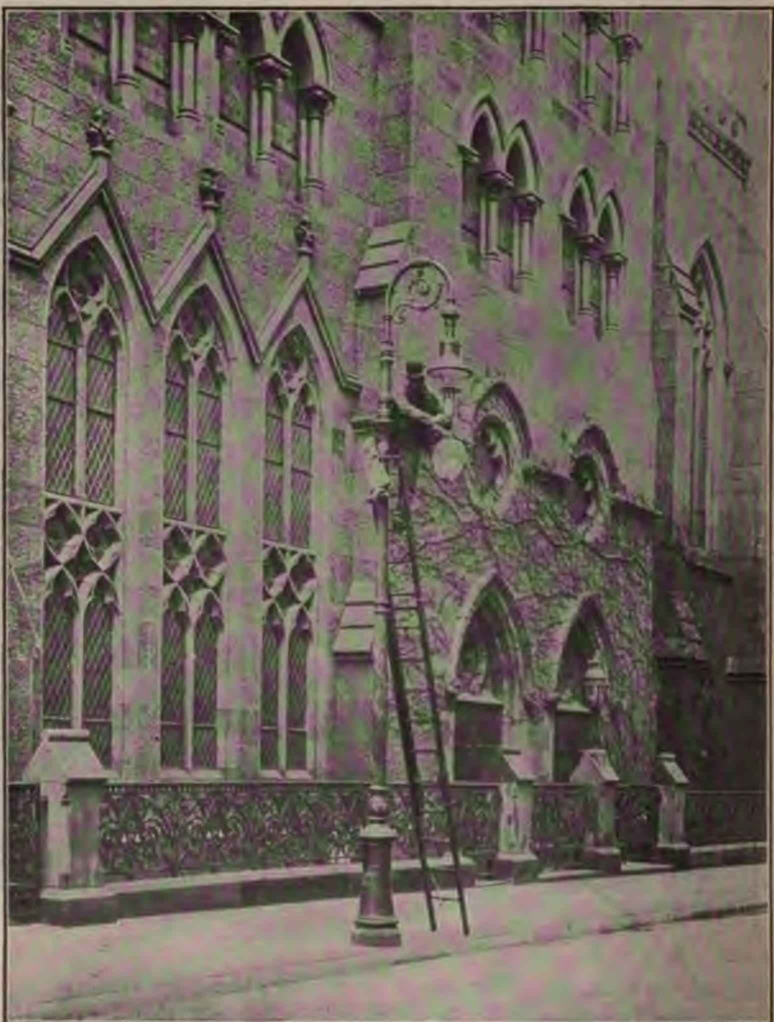


FIG. 9—BISHOP'S CROOK LAMP POST

the number of new lamps sent out, and the length of service obtained from each lamp. In the equipment of the arc-

lamp repair-shop work there are several labor-saving devices of a character exclusively applicable to arc-lamp repairs. The illustrations herewith submitted are a combination carbon cutter and punch for cutting washers, etc., and an inner globe washing machine.

The latter machine is operated by a .25-hp motor, and is constructed with a hollow shaft and an automatic water cut-off so that no water is flowing except when the revolv-

FIG. 10

ing brush is inside the globe. A boy can clean 1100 globes within a day of nine hours with this machine.

There is but little change in the methods employed in trimming the inclosed lamps for street lighting as compared with the old type open-arc lamps. In the congested districts of the city the street lamps are suspended from all iron Bishop Crook posts without steps and an 18-foot rung ladder is used to trim with. For inclosed-arc city lamps—lighted

from dusk to daylight every night—using an 18-foot ladder for trimming—one man takes care of about 85 lamps each day; trimming the lamps, cleaning the outer globes, and changing the inner globes on such lamps as have the inner globes discolored. The route of the city inclosed-lamp trimmer varies daily, the average distance covered being approximately seven miles. For the same class of service in the suburban districts, with the lamps spread over a larger area, the trimming is done with the aid of a horse and cart. The routes vary from 12 to 19 miles, the average being 14 miles a

48th. Street and Seventh Avenue.			~~65~~ ~~CIRCUIT~~
REPORTS	CHANGED		System ~~Brush Series~~
JAN 31 1903	FEB 1 - 1903		D. C. Mul
AUG 22 1903	AUG 23 1903		City Classification ~~A #4~~
JAN 24 1903	JAN 25 1903 -	D. C. Mul	B #4
			Post Equipment
			~~Iron Base Wood Shaft~~
			Bishop Crook
			Remarks

FIG. 11

day, each route being made up of about 115 lamps. The trimming of the city and commercial arc lamps of the Brush, Thomson-Houston and Adams-Bagnall open-arc types, is restricted to trimmers who are assigned to this class of service exclusively. The routes average seven to ten miles and are made up of from 110 to 125 lamps. It is well to confine open-arc lamp trimming—the lamps requiring attention each day—to a route composed exclusively of such lamps, leaving the inclosed-arc trimmer free to change his route from day to day according to circumstances.

The severe requirements of municipal lighting in a metro-

politan city necessitate an organization that will fulfill every requirement and keep the service up to the very highest standard.

About 1100 constant-current, alternating-current, inclosed lamps, connected to overhead circuits in the Borough of the Bronx, and about 800 constant-current, direct-current, open lamps on the underground circuits in Manhattan, are in use for city lighting, in addition to 2400 direct-current multiple lamps. The services of three night linemen in the various districts are available in case of either an open or grounded circuit, and with the help of the nearest patrolman the lineman, except in extreme cases, can repair a circuit in a short time. Night patrolmen are allotted to a territory in which they can see all of the lamps at least three times each night after the lamps are all started. A daily report of the outages in his district is made by each patrolman in a book provided for the purpose. This report is entered in detail and, in addition to the inspector's report, the repairs made are filed opposite the original entry. A simple form of card-filing system is used as an index to the specific reports of any individual lamp.

Each morning the foreman goes over the report of the previous night and stamps the date on the lamp card with a dating stamp. Reference to the dates on the card provides an index so that the previous reports can be ascertained in detail. He is thus enabled to note when the last report was filed against the lamp, the nature of the trouble, and how long the lamp has been in service, and to order a new lamp installed or give orders for its repair. These cards also provide a method of keeping a record of the condition of the post equipment.

In addition to the arc lighting in Manhattan and the Bronx there are 101 alternating-current series inclosed lamps and 356 alternating-current series 25-cp incandescent lamps in the Riverdale section. These lamps, together with the commercial service, are supplied from a 6400-volt transmission line between the generating station at 140th street and Rider Avenue and the Yonkers station. The Riverdale section is nine miles distant from the Bronx district, and it has been found best to operate it as an independent district. The maintenance of the outside equipment and the operation of the substation are both in charge of two linemen. These men trim the lamps, start up the constant-current transformers at dusk and take them off at daylight, inspect the city lighting

after starting time, make minor repairs to both the commercial and the city installations, and take care of all line trouble in their territory. These men report the installation requirements in detail and are governed by the instructions of the Bronx district superintendent.

The 2400 direct-current multiple lamps are connected to underground low-tension mains and are turned on and turned off individually. Failing of the final adoption as yet of an entirely satisfactory automatic time switch, notwithstanding the many types that have been, and many of them still, under test, we have had to resort to the boy brigade to do this work. Boys, preferably over 14 years of age, and almost exclusively school boys, are employed at this work, and for 45 minutes' actual switching work both night and morning receive $2.50 weekly. They are divided in sections and report before commencing work to the regulator at the nearest substation. Three men in charge of the boys cover the entire city, and as the labor is of an erratic kind, care must be taken to learn that the boy is actually at work. The lamp-post keys are withheld until 10 minutes before the starting time and then are given to the boys. Each of the three men call by telephone the various stations the boys begin work from, and in the event of the failure of a boy to report, he takes his place on the route.

The method herein described is perhaps unusual in electric-light service, but it has been found, on the whole, to work satisfactorily.

DISCUSSION

THE PRESIDENT: I want to say one thing in regard to Mr. Rhodes' paper. Of all the papers asked for in advance by members to whom I sent a list of the papers, this paper was asked for by more delegates than any other paper before the convention. Mr. Rhodes' paper seems to be such a complete story of the whole subject that I judge, from the absence of any gentleman arising to discuss it, that there seems to be no member who wants to know more about it. It seems a shame to pass such a paper without a very thorough discussion.

MR. GILCHRIST: Does Mr. Rhodes attribute this phenomenal increase in arc lighting, which the New York Edison company has enjoyed during the past year, to the service that is given by this arc-light department, or has there been any

change in the policy or prices of the New York Edison company which would increase the use of the arc lamp? We are very anxious to increase our arc-light business in Chicago, but we have found it very difficult to do so during the past three or four years. I think I have noticed the tendency recently on the part of the general public to use arc lights again, but I think it is due to a more strenuous effort on the part of the central-station people because they find they are getting such sharp competition from the various types of multiple-burner gas lamps on the market, which are really formidable competitors of the arc light.

MR. RHODES: Mr. Gilchrist has practically answered the question. There has been very little change, from an operating standpoint, within the last eighteen months or two years. The new policy is really the work of our contract department; it brought about so much new business that it was up to me to get in line and hold what it brought. The "lighting engineer" is a new scheme evolved within the last eighteen months, and, as I said in my paper, considerable business came to us from the customers using the Kitson or Humphrey gas burner. The operation of both of these lamps, especially in the winter-time, is very bad, and the lighting engineer, if he is a bright fellow, has his work cut out for him. Our trimmers brought in detailed reports of defective lamps of other forms of illumination of interest to us, and these were turned over to the lighting engineer, who followed them closely. The users of both these lamps could not, in many instances, be induced originally to take the arc lamp, on account of the expense; but after they had used the high-candle-power lamp and then saw that it was failing and that their business was not so good as when the lamp was in good order, it was easy for our agent to come along and guarantee to give them something that would supply the service they required and hold their business. The memorandum forms shown have been a great help to that business.

MR. GILCHRIST: What sized lamps—direct-current, high-tension lamps—are you putting out?

MR. RHODES: Five and 3.25 amperes.

MR. GILCHRIST: Do you furnish the lamps?

MR. RHODES: Yes, sir.

MR. GILCHRIST: Have you always done that?

MR. RHODES: There has been a change in our policy, and that accounts for the large number of different lamps on some

of the routes of our trimmers. We have as many as twenty-five different lamps on one man's route.

MR. GILCHRIST: What size is the 3.25-ampere lamp?

MR. RHODES: That is really a customer saver. If the customer does not want to pay the bill for a five-ampere lamp, a 3.25-ampere lamp will probably induce him to continue the service. If he has ten 3.25-ampere lamps, they will give almost as good an effect as ten five-ampere lamps; not in actual results, but practically so—with the outer globe removed and a flat or deep shade exposing the entire inner globe.

MR. DOUGLASS BURNETT (Baltimore): I ask Mr. Rhodes what is the cost per year of this careful attention and maintenance that he describes? The amount will probably be satisfactory as Mr. Rhodes will give it, but we are likely to underestimate it. I have had occasion recently to investigate this question in connection with one of the large companies of the country, and the cost of this sort of maintenance has somewhat surprised me.

I should like to bring to your attention several points in connection with Mr. Rhodes' paper. On page 121 he says: "The development of the inclosed lamp has opened great possibilities in the exercise of economy, if the maintenance and repair accounts are carefully scrutinized."

There is very little difficulty in getting arc-light business when you work it right. If you go to your customer and point out to him what should be the standards for locating the lamps and the standards for using the lamps, you are in position to give him good and acceptable advice, especially if you take the trouble to submit to him sketches of his store or building, together with a general outline of a scheme for its lighting. It is entirely proper that the central-station man should take toward a storekeeper such an attitude as this: "For the interior of your store you require a five-ampere (at 125 volts) lamp for every 300 square feet of floor space, the lamp to be located with the arc about 12 feet above the floor level. Arc lamps for interior lighting of a store will show goods to customers better than anything else. For your windows you want to make an attractive display of goods, and you should use incandescent lamps." If you say that to the proprietor of a store and he doubts it, you can borrow one of those lumichromoscopes, or use some other device, to prove it. You should tell the proprietor that he ought not to be satisfied with showing goods in the

store, but should go outside to reach the floating populace on the streets. He can not do that by installing a good system of lighting, but he must go further, and influence people at a distance by the use of electric signs.

Even then you have not gone far enough. You must look over the available types of lamps, select the best, and install it at your own expense and maintain and care for it. When you do these things, you will find there is no great difficulty in taking care of the arc-light situation so far as it concerns the meter service.

I am much interested in developing our series service. Mr. Rhodes says the development along that line has not been very great. I dare say the majority of us have a reasonably steady business in series arc lamps; we probably have about the same load as we had two, three or four years ago. By adopting the suggestions in Mr. Rhodes' paper and carrying out the ideas I have just outlined, we can develop our meter business; still, the problem of how to develop series arc-lighting business remains. That is important, for the reason that the gas people have not finished with the development of high-candle-power lamps. The intensive burner is approaching these shores, and we must do something more in the way of development; probably by means of the series inclosed-arc lamp. We have the advantage of fixed hours of lighting service and in prices, half of these applying to the meter service, because of steady load and other conditions, not the least important of which is the saving of the current wasted in resistance in the meter lamp.

I ask Mr. Rhodes the result of carrying out the practice mentioned on the first page of his paper in connection with wholesale contracts. Is it not bad, from a central-station standpoint, to arrange with the customer to have him take care of and maintain his own lamps?

Mr. Rhodes: In a broad way, no; in some instances, yes. If there are six, eight, or a dozen lamps on a class of service where the customer watches his accounts closely, and has his operator take care of them, and the operator also takes care of the elevator machinery and does other work, the lamps will be trimmed in between times, and in such cases results are not apt to be very good; but in a large department store, for instance, where that class of work is given to a regular trimmer, the results have been good. You might infer here that we do not help the customers on the 5400 lamps furnished under whole-

sale contract. That is not true; the customer can get our help when he wants it. If his trimmer leaves him we break in a new man for him at his request. We will get close to his engineer and tell him how to fix the lamps; we will send a man to show him how to fix a particular type of lamp, so that he does not have to get the outside help—often incompetent—who will charge him 60 cents or more an hour for something that does not mean more than the turning of a screw-driver or the truing up of a clutch.

MR. BURNETT: What is the maintenance per year?

MR. RHODES: I do not know whether or not I can give you that in detail; I do not know that I have the authority. One man, at $12 per week, will take care of 650 lamps; we have had them take care of 750 lamps. One trimmer, seven days, at $14 a week, will take care of 650 city lamps. In the repair shop one man will take care of 2000 inclosed lamps; that is not expert labor. One man at $3.50 per day, and the rest at $2.00 per day, will do the work; one man to furnish the brains and detailed information, and the rest of the men to follow his instructions; one man to do the adjusting, and the rest to make the minor changes and repairs, and that sort of thing.

MR. BURNETT: I wish to point out the great value of the services of Mr. Rhodes' trimmers, as indicated on page 125, where he says: "A useful report turned in by the trimmer is that covering a change or contemplated change in the system of illumination." One of the things that central-station men must do carefully is to urge each man in their employ to use his brains and best thought to every possible extent, aside from the specific work that he is directed to do.

The night linemen in various districts who are available in the case of either an open or a grounded circuit, and who with the help of the nearest patrolman—except in extreme cases—can repair a circuit in a short time, may well be used in the early evening for switching on electric signs and later switching them off again. These men do this in Baltimore with great success.

Referring, finally, to the use of the automatic time switch. In connection with a stable supply or fixed installation—such as a show-window with a definite number of lamps of a definite candle-power, or an electric sign—it is sufficient in the last analysis to consider the time switch the equivalent of a meter.

MR. GILCHRIST: Does any company represented in this room supply diffusers free to its customers?

MR. RHODES: Yes; the New York Edison company does so.

MR. H. A. HOLDREDGE (Omaha): The Omaha Electric Light Company does the same.

MR. GILCHRIST: We are anxious to find out about that.

MR. BURNETT: Our company is prepared to do so if the General Electric Company will adapt the diffusers to other than the General Electric apparatus.

THE PRESIDENT: We will close the discussion on this paper. I am very glad to call your attention to the next paper on our programme. It is by one of our past-presidents—one who has probably given more attention to the affairs of this association during the last fifteen years than any other man connected with the association. I am very glad to call on Mr. James I. Ayer, of Cambridge, Massachusetts, to read his paper on electric heating.

The following paper was read by Mr. Ayer:

ELECTRIC HEATING AND THE FIELD IT OFFERS CENTRAL STATIONS

Electric Heating is a subject of growing interest to the central-station manager, and from the past few years' experience, I can say it is worthy of all the consideration that may be given it. Its development generally has been much slower than any other application of electricity, and the reasons are not far to seek. As far back as fifteen or sixteen years ago, when the electric motor was seeking a foothold and alternating current was grudgingly being given a place in the family of "systems," electric flatirons and electric cooking devices made their appearance.

The earliest work of a substantial character was begun by the Carpenter Electric Heating Company, of Minneapolis, in 1889, and continued through a checkered career for several years. Other companies were numerous and short-lived, as most of them deserved to be.

While the earliest products were not all that could be desired, and much crude experimenting was conducted at the expense of the enterprising public, some of the product justified itself in the way of fair performance. Had there been a more general use of current in residences and industrial establishments, to make the market worth while, a different history would have been written. Considerably less than ten years ago there were few central stations outside of the largest cities that supplied current in the daytime. In such cities the rates were high, with the use of constant-potential current limited largely to the most important stores, few residences, and fewer industrial enterprises. The isolated plants were small and were used entirely for lighting for a few hours a day.

Six or seven years ago the conditions rapidly changed, but prior to this, because of the early numerous failures of electric-heating companies and the sad experience of the public with much of their product, electric heating had become as much discredited as had the storage battery earlier. Extraordinary efforts were required to place the storage battery where it right-

fully belonged, even several years after its revival abroad pointed the way, so strong was the prejudice of our fraternity due to their faith in tradition. Electric heating, while not meriting the same consideration, was very seriously retarded in its development by this same prejudice, and after eight years' effort, during which period much improvement had to be made to make possible such success as has obtained, I can say that the present results would have been achieved much earlier had there been no past.

The future of electric heating is assured, and yet it has in it disappointing elements for its advocates who do not rightly comprehend its limitations. In the early days of electric lighting, the salesman confidently asserted that all the speculative dreams of the inventor could be accomplished by anyone who would purchase his particular dynamo and appliances. Electric heating is capable of being misunderstood to a considerable degree. The engineer, without some thought, will wonder how we can successfully heat with electricity the staterooms of an ocean liner, competing with steam, while deriving power from steam, when we can not heat an office with current from water-power at $30 per year per horse-power, or by meter at three cents per horse-power; yet it is true. If this is a problem to an engineer, how does it appeal to the layman? It will be found that many things are possible that are not commercially practical, and many that appear so are not, and because of this I want to appeal to you as central-station men to get a grasp of the elements of electric heating, and a knowledge of working conditions, that you may move rapidly and reap the benefits of intelligent application of this branch of development.

For residences, in all cases, the rates for lighting are the highest charged for any service.

Because of necessity this is so; on account of relatively small return for the investment and maintenance cost required to supply a residence as compared with other service, it is important that the customer may increase the usefulness of his supply without materially increasing the cost.

Electric lighting costs more than gas, directly, but its many advantages, such as cleanliness, convenience and safety, are gains that are now appreciated to have a cash value.

The use of fans and sewing-machine motors is not possible with gas, and the operating expense is slight. By adding more of such elements in the home—which gas can not supply, or

only in a crude, imperfect way—your position becomes impregnable, for what your customer can get will be well worth the price, and the cost not high.

There are many convenient electric heaters of small current consumption that are effective in supplying wants that gas can not meet, or when possible with gas, the contrast is even more marked in their favor than a comparison of the two methods of illumination, and I will mention some of them.

Electric curling-iron heaters use 50 watts and are never in service more than a few minutes at a time. The electric heating pad, or substitute for a hot-water bottle, is an invaluable device when required, and uses but 50 watts. Electric flatirons are made for sewing-room use of 200 or 300-watt capacity, and though frequently in commission the period of operation is short, so that the monthly consumption of current is small. They save many weary trips to the kitchen for a hot iron to press a seam, a bit of lace, and not infrequently Johnny's trousers.

An electric tea-kettle or stove using 200 watts, or a small cup with heater, will produce afternoon tea for two, heat the baby's milk night or day, heat shaving water, and is of much value in the sick-room. With two small stoves, a breakfast of eggs, toast and coffee can be prepared on the dining-table while you wait, and you will not wait as long as usual.

A chafing-dish is of course more useful for general cooking in the dining-room, and until one has "lived with an electric chafing-dish," he does not know its possibilities. These require 200 or 500 watts, according to size, and are cheaper to operate at lighting rates than the alcohol kind.

An automatic coffee-urn for the breakfast table does its work perfectly in from ten to twenty minutes, using 200 to 400 watts, according to size.

For the man of the house, inclined to tinker, an electric soldering iron, using from 100 to 200 watts, is useful, as well as a small glue pot.

All of the above-mentioned articles are usually supplied with lamp socket plugs, and are sold ready to connect. There is nothing in the way of special work required to put them into service: their operation is quickly understood, and most are of such low price as to be easy to introduce. Such articles are the best possible advocates for the more extended use of the electric service in the household, and will do much to make a satisfied

customer. The fact that, except the heating pad, none of the articles is at work for more than from ten to thirty minutes at a time makes the aggregate for the month but a small addition to the total bill, yet a material gain to the station, for it is added output on existing service wires, and the articles serve as missionaries.

Every residence customer on your lines should be systematically informed of the advantages of these small items, their introduction urged, and a record kept of the purchases. The use of the above leads to a demand for electric-cooking appliances for the kitchen, and irons for the laundry.

How does the cost of electric cooking compare with gas? Here we have a burning question.

If electricity and gas could be used at equal efficiencies for the various cooking operations, this topic would have been omitted, but fortunately that is not the case. Electric-cooking apparatus easily operates at an average efficiency of about 70 per cent, and gas at about 15 per cent, in ordinary practice in domestic kitchens. I am aware that some gas operations show a much higher value and others less, and in the hands of experts better average results may be obtained, but this is equally true of electric apparatus. Jane may turn on the oven of either system half an hour in advance of the time required. She can run the burners under the kettles wide open and waste at a greater rate than by treating the electric heaters in the same manner, for they have a fixed maximum, and it is all heat; but whether gas or electric cooking is reasonable in cost depends much on Jane. I trust you will pardon me if I say gas varies in quality. It is credited with having from 600 to 800 heat units per cubic foot, and it depends on the pressure, location, kind and condition of burners, as to whether complete combustion occurs to develop all these heat units. Assuming that under average conditions 700 heat units are available for every cubic foot of gas, we have 700,000 heat units for a thousand feet. One thousand heat units equal .2909 kw-hour. Allowing a drop of one per cent between meter and heater gives us .2938 kw-hour for 1000 heat units. On a basis of 15 per cent average efficiency for gas ranges, we have effective 105,000 B. T. U. in each 1000 feet of gas.

Electric heat at an average efficiency of 70 per cent equals .4197 kw-hour per 1000 effective heat units, and for 105,000 effective heat units there would be required 44.065 kw-hours to

give the same results. To compete with gas at equal rates electricity will have to be sold

at 5.67	cents	per	kw-hour	where	gas	is	at	$2.50	per	1000	feet
" 4.54	"	"	"	"	"	"	"	2.00	"	"	"
" 3.40	"	"	"	"	"	"	"	1.50	"	"	"
" 2.83	"	"	"	"	"	"	"	1.25	"	"	"
" 2.27	"	"	"	"	"	"	"	1.00	"	"	"

The above is, I believe, as fair a comparison as can be made where exact comparisons can not well be secured. The results above quoted have been checked by records made in the same family alternately using gas and electricity each week for considerable periods in a number of cases, and from a variety of records obtained otherwise. It is assumed that suitable equipments both of electric and gas appliances are used.

It is a fair statement that in a family of four or more, with a suitable equipment and ordinary care, it will require from one to one and a half kw-hours per day per person. Taking the higher value, this at three cents per kw-hour is four and one-half cents per day or $1.35 per month per person, and for a family of four equals 18 cents per day or $5.40 per month; at five cents per kw-hour, it is seven and one-half cents per day or $2.25 per month per person, and for four, 30 cents per day or $9.00 per month. If economy is practised these amounts, at the respective rates, can be reduced about one-third. Our recorded data show an average of about 20 per cent less than the highest value quoted.

As far back as 1897 (Transactions American Institute of Electrical Engineers, 1897, p. 484), Professor John P. Jackson, at Philadelphia, using much less efficient apparatus for many operations than is now supplied, recorded carefully all current required for all cooking for a family of six, and the average was 830 watts per day per person. Professor Jackson kept accurate account and the operator undoubtedly used greater care than can be expected in general practice, but his apparatus was less effective than that which is available to-day, and it should also be mentioned that the value stated includes that required for the hot water for washing the dishes. It is a fair statement that, where care and intelligence are applied, the cost for a family of four need not exceed $4.00 per month at a three-cent rate, or $6.00 per month at rate of five cents per kw-hour.

It must be understood that the above costs for cooking do

not include heating water for the bath or laundry purposes. If they did, we could give even coal a close race at summer rates for current. Indeed, for cooking most meals, electricity at three cents per kw-hour is close to and sometimes less than the cost for coal if no other use is made of the fire, but here we find the hot-water supply is incidentally cared for.

While it is clear that low rates are necessary to popularize electric cooking generally, it is a wide field at higher cost than its competitor, gas, and for the same reasons that gas has had such generous recognition, although it costs more than coal.

In the households of those whose work is all in the hands of servants, the advantages of electric cooking will not appeal, because economy is not the rule. Existing methods give satisfactory results, and the details of method are of no interest. In houses where the work is in the hands of ignorant "help," there is not a good field to-day, but in the home where the mistress is the cook, entirely, or in part, and in small homes in our suburban towns and in the smaller cities, the field is wide.

The apartment-house kitchen, supplied with hot water from a central source, affords a fine opportunity for electric cooking. The freedom from heat, offensive products of combustion, and leaky valves; the inevitable soot, dirt, and chance explosions incident to gas, and the absence of all cooking devices between periods of use owing to the portability of electric heaters, are tangible advantages, in addition to the more perfect results obtained when you can cook by the clock, not by guess.

In thousands of homes, gas is used as an auxiliary to the coal range, for some of the lighter meals at all seasons and for much of the general cooking in summer, when the range is not required to be put in commission for other purposes. For all such purposes, electric cooking is not only possible, but more attractive and satisfactory, all things considered, than any other method.

While it may require slightly more instruction at first to get the best results with electric apparatus because of greater general familiarity with the use of gas for such work, yet after a brief acquaintance the certain results that follow in a given time with the current on, or with a given position of the regulating switch, become known, and the clock is depended on. There is no more frequent opening of the oven, or lifting the lid; and we all know it is well "to keep the lid on" for best results.

That this is the ideal method is apparent from a very brief investigation. Simply to turn a switch, and have, without flame or any visible effect, the broiler, stove, griddle, waffle-iron, or oven, change its temperature from that of a room to a point necessary for perfect cooking in from two to five minutes, savors of magic.

A variety of cooking devices, each perfectly adapted to its work, entirely independent of one another, separately controlled, having fixed temperature limits so that successive operations may be performed under exactly the same conditions, all operating with no measurable effect on the room temperature, constitute in brief the electrical method. When it is realized that the principal reason for the failure of the cook to reproduce her best results is because the heat supply fluctuates between such wide limits, due to improper care, we can see what opposition we shall meet from the doctors when they realize that this personal equation is being eliminated from cooking operations. Exact methods are the only ones that will yield uniform results. Imagine your central-station service with the boilers controlled in the manner of the average kitchen range.

In arranging electric-cooking apparatus, we have departed from the conventional form of fuel stove or gas ranges, because electric heat permits of more convenient arrangement, and an electrical outfit can be extended to meet increasing demands without affecting the usefulness or efficiency of the original equipment. A panel-board on the wall with a number of plug switch receptacles and an ordinary kitchen table constitute all of the necessary fixtures; the heating devices consisting of ovens, disc-heaters or stoves. Broilers, griddles, or the two in combination, waffle-irons and water heaters, all of which are light and portable, permit the selection of a more or less elaborate outfit for a family of four, which on occasion may be expanded to meet the requirements of ten times that number without changing the effective value of the first selection. One can start with one or two articles and gradually add to the equipment as may be desired.

All cooking utensils for the kitchen are preferably made without heaters, so that a variety for different operations may be used on a single heater. More utensils than heaters are always necessary for general cooking, and vessels without heaters are much lighter, more convenient, more easily cleaned, and of course cheaper. In all cases, utensils made specially for

electric stoves should be used with them, as they are designed to fit and temporarily become a part of it while in position. Dissatisfaction with disc-heaters is the result of operating them with improper vessels.

Besides the above, there is a demand in residences for electric plate-warmers, electric water heaters for bath-rooms, laundry irons, and electric radiators.

Electric plate-warmers are usually placed in the pantry, and supply a want but imperfectly met heretofore. They are not expensive to operate for those who demand them, and they should be suggested when arrangements are made for installing wires. The large heat capacity of water makes heating it by electric heat in quantity expensive, yet for bath-rooms it is becoming more and more in demand. Five gallons of water heated to 190 degrees, when added to 10 gallons of water at hydrant temperature in a small bath-tub, will provide one with a warm bath, while eight gallons at 190 degrees, added to 15 gallons at the hydrant temperature, would be more desirable. The former would require 1750 watt-hours, which at five cents per kw-hour is 8.75 cents, and the latter 2800 watt-hours, costing, at the same rate, 14 cents. This cost is not excessive, but it means heaters of 1750 and 2800 watts capacity, respectively, which must be turned on an hour before the water is needed. If the work is to be done more quickly, then correspondingly larger heaters and service wires are necessary. We frequently supply pressure boilers connected to the water mains containing heaters of smaller capacity, which are arranged with subdivisions of heat, which may be kept on continuously at low heat, and at low rates they are not prohibitive.

Small heaters for wash-stands, which may be connected to the supply pipe, are being developed, but for such use a small cup that will quickly heat to the boiling point a pint of water (requiring for this about 850 watts for three minutes) is useful, and current is not so likely to be wasted. The cost for heating water to different temperatures at different rates is here given, which best tells what is required in current supply for a given result in quantity, temperature, and time as well.

INITIAL TEMPERATURE OF WATER, 60 DEGREES FAHRENHEIT
EFFICIENCY OF APPARATUS, 85 PER CENT

ONE PINT

Total Temperature	Watts used for 5m.	10m.	20m.	1 hour	Cost in cents with current at 3c.	5c.	10c.	20c.
100 degrees Fahrenheit..	164	82	41.04	13.68	.041	.068	.136	.272
150 " "	372	186	93	31	.093	.155	.31	.62
175 " "	468	234	117	39	.117	.195	.39	.78
200 " "	576	288	144	48	.144	.24	.48	.96
212 " "	624	312	156	52	.156	.26	.52	1.04

ONE QUART

Total Temperature	Watts used for 5m.	10m.	20m.	1 hour	Cost in cents with current at 3c.	5c.	10c.	20c.
100 degrees Fahrenheit..	324	162	81	27	.08	.136	.272	.544
150 " "	744	372	186	62	.186	.31	.62	1.24
175 " "	936	468	234	78	.234	.39	.78	1.56
200 " "	1152	576	288	96	.288	.48	.96	1.92
212 " "	1248	624	312	104	.312	.52	1.04	2.08

ONE GALLON

Total Temperature	Watts used for 5m.	10m.	20m.	1 hour	Cost in cents with current at 3c.	5c.	10c.	20c.
100 degrees Fahrenheit..	1296	648	324	108	.32	.544	1.088	2.17
150 " "	2976	1488	744	248	.74	1.24	2.48	4.96
175 " "	3744	1872	936	312	.94	1.56	3.12	6.24
200 " "	4608	2304	1152	384	1.15	1.92	3.84	7.68
212 " "	4992	2496	1248	416	1.25	2.08	4.16	8.32

The equipment of domestic laundries will be found a profitable field. The family requiring but one iron will need a size using about 500 watts, and it will be in demand from five to ten hours per week, according to the size of the family. This means from 2500 to 5000 watt-hours per week. In many families, the larger portion of this work is sent out, leaving even less to be done at home, and of course less weekly use of the iron.

The advantages of the electric iron are conspicuous. The temperature of the room is normal, and that of the iron uniform; it requires no cleaning, no time wasted going to and from the stove, and every rub counts. In the house of the man of moderate means, as with electric cooking, it is most used in hot weather, but if encouraged by low rates, it becomes a habit. In the homes where one or more servants are regularly employed in the laundry, much attention is paid to its sanitary condition, and there electric irons are rapidly becoming essentials.

Radiators are in demand, and are used to advantage, but it is not possible to do usual office or house heating unless current

may be obtained at exceptionally low rates. An application that is reasonable is the use of one in a bath-room for taking off the chill during the morning bath. For such work a radiator of less than 1500 watts capacity is not to be recommended, and one of 2000 watts is better. The latter operating from fifteen to twenty minutes will usually answer requirements, making a total consumption of from 500 to 800 watt-hours. There are other special conditions where they are sometimes used to advantage. Being easily portable, they are valuable about the house for occasional use for short periods.

For electric cooking and electric laundry work in the home, it is clear that special rates, lower than can be made for lighting, are essential to success. The load being principally a summer day load makes special low rates possible, and the business desirable.

One method that has been practised is to install a separate meter, making no restrictions as to the amount to be used, thereby offering all possible encouragement to the customer. Another plan is to use two-rate meters. Rates on either plan, in most communities, may be made with profit as low as five, and in many cases as low as three, cents per kw-hour for day service.

Electric laundry and tailors' irons have had the widest use of any single line of electrically-heated devices, and to-day offer the broadest single field for development. Being best known, perhaps, of all electric-heating devices, it is perhaps worth while to examine them in detail, in relation to the requirements and how well the demands are met.

The home needs and how they are met have received attention. Hotel and commercial laundries demand irons for constant and rapid work. In the majority of cases these are heated over gas burners. The rooms are usually small, and when the gas stoves have done their best it is a place to avoid ; yet here we send our linen to be cleaned. Though this is generally true, the improvement in the financial condition of laundry owners in the past few years is such that they are seeking better methods, and are in many cases looking to you for help in improving the efficiency and sanitary condition of their establishments. The same is true of many clothing and similar factories.

The electric iron while working is passed rapidly over damp and frequently wet fabrics with pressure constantly

applied. This treatment demands a rapid supply of heat for the work, and for the constant loss by radiation, which, though not a large element at the normal working temperature, still is a constant loss. Irons are made with a given generator capacity for the different classes of work, and if they are continuously employed in the regular manner their temperature is fairly uniform and results are satisfactory. When for any reasons the irons are left with the current on idle for even five minutes, their temperature rises to about double the normal working value, and according to their construction the generator or winding within the iron goes much higher; in fifteen or twenty minutes the temperature is still higher, which submits the heater to strains that finally become destructive. It is because of this treatment that, until improvements were made to enable them to better withstand this treatment, the product was unreliable.

To-day it is still difficult to construct irons for rapid work that will give good service without some arrangement to prevent the overheating when idle. One device that accomplishes this operates automatically to reduce the current supply whenever the iron is placed on its stand, and this incidentally effects a saving of 25 per cent or more during such periods. One other fault incident to overheating, not confined to electric irons, is their liability to burn the garment on which they are first placed when in this condition. Complaint is sometimes made about the breaking of flexible conductors, and this is always a serious fault in improper installations. Cords should be no longer than necessary to permit the free use of the iron. If they are connected to the circuit by a plug switch, placed 20 inches above the table on the wall back of the bench and suspended by an elastic cord and string from the ceiling so there is not more than two inches of slack between the point of support and the iron when placed in the centre of the bench, there will be no complaint of the cords.

All irons should be provided with a suitable ventilated stand and with no other kind.

The advantages of the irons are conspicuous: they are always clean; heat in from four to five minutes; will operate continuously and may be kept at practically uniform temperature under all conditions of service, and when controlled have long life and, in the best products, in common with other types of electric heaters, do not change their resistance with continued service.

The cost for operation per hour varies with the size. For the all-around use for domestic requirements without a regulator, the most efficient use from 500 to 550 watts. The regulators effect a saving in such service of from 15 to 20 per cent.

In laundry work in hotels, and commercial laundries, the irons vary in size, and their consumption is from 350 to 600 watts per iron, and the regulators effect fully 20 per cent saving.

In clothing and similar manufacturing establishments, the tailors' irons are larger and require from 600 to 1000 watts per iron, and the average is perhaps 750 watts. Except where electric irons are used, gas irons with burners within them, connected to the supply with rubber tubing, are almost invariably used. They have no end of trouble with leaky tubes, which frequently burn off, break or slip off the connection ; combustion is more or less imperfect, and they are dirty. All of this makes a bad sanitary condition and a constant source of trouble.

While many use electric irons the change has barely begun, and the reason is largely due to the failure to secure attractive rates ; from three to five cents per kw-hour is what is necessary to handle this class of work, which in many cases should demand and secure such rates, for these customers are (especially the garment factories) entitled to your best consideration.

It is pleasant and interesting to state that I know of not a single establishment that ever adopted electric irons that changed to other kinds, and I know of several considerable installations that have continued their use for more than twelve years. With this showing, and the present improved product, there is no reason why this branch of electric heating should not develop important additions to your output.

In commercial laundries, the heating of ironing rolls has been done electrically, and in book-binderies the electric heating of presses and other machinery has been carried out to a considerable extent.

Some electric cooking can be developed in the use of stoves for the noon-day meal for clerks, and when no cooking is desired, a heater or two for warming the lunches and hot-water heaters for making tea can frequently be placed.

Book-binderies, pattern shops, furniture stores, and many other establishments, find glue heating expensive, dirty and

dangerous with gas. Electric glue pots operate cheaper, and are entirely free from all the objectionable features of the others. There are dozens of establishments equipped with twenty or more each, and many hundreds in use in smaller groups.

Electric sealing-wax heaters are used by jewelers, banks, express companies, and others.

Soldering irons have a considerable field in small shops and some classes of manufacturing. These articles have had limited durability, owing to the necessary high temperature when working effectively. Because of their form they are easily constructed, but not to stand the severe duty. Later improvements in construction and the use of an automatic temperature regulator have made them a very satisfactory product. Special rates are not necessary except for considerable installations, as the cost of operation is usually lower than for gas irons.

Hot-water urns for barber shops and bars, as well as for lunch-rooms, can be installed. Doctors' offices and hospitals require sterilizers for instruments.

Manufacturing establishments have many applications of heat to machines where electric heat is frequently applied at a saving in cost. With all applications it is important that a responsible representative gain full knowledge of the apparatus, its workings, the proper methods of installation; then see that the customer is clearly instructed in all essentials for its proper care, operation and maintenance. Too much is taken for granted as to the customer's understanding in this respect, which frequently develops unconscious abuse, resulting in annoyance, interruption of service, and frequently avoidable expense.

As to the durability of apparatus, it can be asserted that the general product of experienced manufacturers will give quite satisfactory results if the above remarks as to acquainting customers with what is necessary for fair treatment are heeded.

Perhaps a statement of performance will give a better answer regarding durability than could be given in any other manner. In the winter of 1902–3, about a year and a half ago, the Natural Food Company, of Niagara Falls, New York, began the manufacture of a new product they call "Triscuit," it being a cracker of shredded wheat baked or toasted by having heat applied to both sides at the same time. The operation consists of passing the product through a machine between two endless

link belts inclosed except at one end. The links of the belts are electric stoves, and are so arranged that the triscuit is fed in and held pressed between the faces of two stoves throughout the complete circuit of the machine. The operation is continuous. Each machine has about 2500 stoves and has a product of 17,500 triscuits an hour. They are operating about 10,000 of these stoves and their failures up to date have been less than one per cent from all causes.

This is the largest development of electric cooking in the world, and is successful in every way; the cost for baking, including labor, being less for the same amount of product of triscuits than for shredded wheat biscuit using coal. When the plan was presented, I agreed that we could build successful heaters, and that the cost of operation would be reasonable. Results show that if power were derived from steam the statement would still hold good. There is no practical way of baking by applying heat uniformly on both sides at once under pressure except by electricity, and the method has advantages.

In conclusion, I want to refer to some of my previous statements. In the comparisons I have made, I have not tried to make the best nor the worst possible case, but I have stated results developed in practice which a considerable experience leads me to believe are results you will derive. In giving you a basis of costs, I am confident your experience will show they are fairly stated.

I want to say that you must not consider doing house-heating from steam-generated electricity, yet you do not want to consider electric radiators impossible. Remember that you will frequently have problems presented that at first appear impossible, that will often be most feasible; that with installations your duty is not done, until your customer's new departure is in good running order, *and you know it.*

Gain personal knowledge of electric cooking from an installation in your own home, and accept the manufacturer's advice in the selection of the outfit. Do this also with other articles of domestic use as far as you can.

I have shown you that for cooking, especially low rates must be made. That most of you can make these rates is a reasonable claim. The load is an added day load and largely a summer load. It is added in most cases to idle transformers, to idle lines, and to running machinery, which in most cases is likely to be operating at low efficiency. For a con-

siderable additional load, it means in many stations an addition for cost of coal only, and in many instances it will be less for this addition than your present cost per kilowatt for this item.

Until electric competition developed, gas companies made no progress with heating. They maintained high rates and limited outputs, never realizing the splendid chance for benefiting themselves and the public until they were literally kicked into it. The stimulus to enterprise is adversity, if you do not get too much of it. Central stations of this country have in most cases experienced years of struggle to reach the satisfactory results finally obtained. With this splendid record that you have made, and the substantial results already achieved in the new field, consisting of upwards of a thousand complete electric kitchens, more than 50,000 smoothing irons, and the many thousand other items which I can vouch for are in practical operation, it needs no prophet to say you will accept the opportunity and get the business.

DISCUSSION

MR. F. G. PROUTT (Memphis): Assuming that we were to carry out the suggestions of Mr. Ayer, what number of dollars per kilowatt of installation might be expected in the way of revenue per year?

MR. AYER: That is a leading question, difficult to answer. You have an undeveloped field. It is difficult to settle what you can do in the way of expanding business; it is like asking what you can get in dollars and cents by a new departure in your lighting department. That you can add materially to your output there is no doubt. Electric heating is an attractive thing to customers if it can be made economical.

As to the question of methods, you can add materially to your output if you adopt the method advocated for arc lamps—install kitchens free. There are a number of ways in which you can get results if you apply literally the methods applied to arc lamps. This system is carried out by the gas companies with great success. Something like $100,000 was invested in gas stoves in and around Boston in one year, which were practically given away.

A kitchen outfit for the average family of from four to eight persons would require a transformer capacity of about 30 amperes, or three kilowatts. The average demand would be about 20 amperes, or two kilowatts, at the dinner-cooking hour,

or about two-thirds of the maximum. For other meals it would require something less.

MR. N. T. WILCOX (Lowell, Mass.): If it is used all the year round, which I understand you recommend, how will it affect the peak of our load?

MR. AYER: I think the question can be fairly answered by quoting the experience of the gas companies. Except in the case of apartment-houses equipped with nothing but gas stoves, there is practically no winter load. For apartment-house work a two-rate meter would take care of the peak by paying you for the service at the lighting rates; but in my opinion this peak load may well be ignored in considering the introduction of electric cooking. This is a problem that will have to do with the extent of the development of the service. It would seem quite reasonable that in most cases it would not add much, if any, to the peak load. I doubt if you would refuse a low rate to a customer who is going to use electric cooking the year round, who would add to his present lighting bill four or five dollars per month for cooking where at least 90 per cent is used in the daytime. Of course this is a question for each company to determine. Most of the load for cooking is off by six o'clock, as the demand for current for cooking ceases some little time before the meal is to be served, and it is fair to say that six o'clock, or perhaps half-past five o'clock in many of the kitchens, would see the bulk of the load for cooking going off.

MR. WILCOX: I would ask if Mr. Ayer has any information in regard to the household applications, such as cooking, where a complete outfit is put in, as to the demand, for instance, on a transformer, and the load factor based on that demand and its effect on the peak load?

MR. DOW: I have been footing the bill for an electric kitchen. I have arrived at several conclusions, which I will now pass out to you; but if anyone wants to get me into a corner and argue the matter I want him to give me notice, so that I can bring Mrs. Dow to help me out. She is responsible, rather than myself.

We have four or five kitchens on our lines where electricity is exclusively used, but only one of them is under my personal observation. My conclusions are as follows: The cooking peak load is in advance of the usual maximum lighting peak in the residence district. That means, in our town, that it

coincides with the down-town peak. It will require no additional substation machinery, but it will add to the main station peak for the winter months only. The next conclusion is that the cooking load is about two hours per day through the year; say 700 hours of the demand of the district—not the demand of the individual customer, but the demand of the district. The next conclusion is that it does not do to sell cooking discs, and so forth, unless you look after the kettles. You can waste about half the current by having the wrong kind of vessels to put on the discs. An absolutely clean, smooth vessel is better than the ordinary cooking utensil; and the best is the type of vessel that clamps solidly on the disc. The next conclusion is that cords are a nuisance and are constantly causing trouble. They get greasy and grease the food and the apparatus, and should be cut off as short as possible. While we are waiting for some method of wireless connection for cooking utensils, I have adopted the plan of passing the cord down through a hole in the table and letting it loop underneath, as do the cords of a telephone switchboard. This works nicely and gets the cord out of the way.

The next conclusion is that the different devices furnished for varying the heats are bad things in the hands of the ordinary kitchen mechanic. They are mismanaged and broken. I believe that two heats, in practice, are sufficient; one quick heat and one simmering heat. These can be obtained by a double-throw switch, which when open cuts the heat off altogether. In my opinion the best method of wiring is the double-throw switch on the wall, with the cord running down behind and up through the table, and with only two heats available.

My last conclusion is gathered from the experience of my neighbors and myself with a number of different makes of apparatus and utensils for electric cooking. It is that the worst fault to be found with electric cooking to-day is the repair bill. The load is a desirable one, I think. The rate might be cut down to a point where there would be considerable business, particularly in apartment-houses and with the numerous households where the wife does her own work; but the repair bill is very serious. I want to say that this statement is not based on experience with any one class of apparatus, but with a number of makes of apparatus; and there seems to be a lot of difference, not merely between makers, but between different productions of the same maker.

Mr. Arthur Williams: I think this paper is timely and important and that our members should preserve it carefully for future reference. Our company in New York has constantly received applications for just such data as these from contractors, engineers and others who wish to be informed upon electric heating and cooking. We recently issued an illustrated circular on this subject, the first edition of which was 30,000 copies; this edition was quickly exhausted and several others have followed—since likewise exhausted—showing the very general interest upon the subject. The circular illustrated a variety of utensils and devices, giving the range of their cost and the approximate cost of operation for periods of fifteen minutes—about as long as their average use at any one time for a given purpose. It will be admitted, I think, that electric-cooking apparatus will never return such a revenue as is obtained from other classes of installation, like lighting and power, as, naturally, the daily periods of use can at most be short; but, apart from cooking dinner in the late afternoon in the winter months, whatever revenue comes from this source is entirely additional to all other revenue per kilowatt of installation. This fact in itself should encourage the companies to push forward the installation and use of electric heating and cooking apparatus, and, in addition, it offers the companies' customers much in the way of convenience as well as necessity if the use of electric current is made more popular. Any cooking apparatus used in the months of June, July, August and September can not come on the peak of the general system or of the converters, and it has occurred to me that any residence lighting in these months is of so very little importance that it may be a good plan to adopt the method of charging half the normal rates for all current used during these months. A new schedule has recently been adopted in London under which all "hidden" lighting—that is to say, the lighting below the street level—is charged for at exactly half the normal rates at all seasons of the year. If the usual rate is 12 cents per kw-hour, the rate for the installation below the street level is six cents. It is said that this schedule has been very successful in competing with gas and other forms of illumination. One advantage of such a change would be that no extra metering, wiring or converters would be required, and in addition to encouraging cooking by electricity during the

summer months, household users might be more inclined to install fans, and thus add materially to the summer load on the system.

The question of rates, so far as cooking is concerned, seems of little importance. Any rate used for incandescent lighting would seem to be low enough to encourage this branch of the service. I recall several instances where small stoves, French coffee pots, heating-pads (than which there is no greater convenience in the household as a substitute for the hot-water bottle), current for heating dishes, small irons, and so forth, have been used without any apparent increase in the bill. If the members will take the trouble to figure out the quarter-hour cost, they will see that it is so low as to justify its being generally advertised by the companies. Great care should be taken that when these heaters are not in use they should be disconnected. A recent instance occurred in which a customer, having such a heater in his bath-room, left it connected when his service was cut off for the summer; it was still connected when the current was turned on in the fall and continued so until the first bill was rendered. Naturally the bill was unexpectedly high and caused great disappointment and not a little suspicion until the cause was discovered and removed. Some trouble has also been experienced through the absence of indicating devices showing the connection of the apparatus when the current is turned on. Servants are universally careless in such matters. In one recent instance the butler, rather than have the blue or red light burning, turned it out of the socket, so that there was no indication of the use of a plate-warmer. It immediately became the cause of serious disturbance in the company's relations with that customer.

We have a large hat factory connected with our mains in New York where electric irons are now used in place of the gas irons formerly employed. The price of eight or nine cents per kw-hour is competitive with the cost of gas at $1.00 per thousand feet. The monthly bills for the electric service correspond closely with the previous bills for gas. The advantages over the former methods, as given by the proprietor of the establishment, are that the men work faster, increasing materially the output of the factory; the factory itself and the surroundings about the men are cleaner; the atmosphere is cooler, and with the use of electric irons the work is much less fatiguing for the employees.

THE PRESIDENT: Gentlemen, we have spent a considerable time on this subject and shall have to close the discussion. We will take up the next business, which is the report on lost and unaccounted-for current, presented by Mr. C. W. Humphrey, of Denver.

Mr. Humphrey presented the following report:

LOST AND UNACCOUNTED-FOR CURRENT

I will endeavor in the course of this paper to explain in full the calculations of losses, known and unknown, for alternating and direct-current circuits, and to give the records of some of the results we have obtained and tabulated during the past two years. Most of the data herein given are compiled from results obtained on the lines of the Denver Gas and Electric Company.

Our lines here in Denver are now all 2400-volt, single-phase feeders, but the calculations are approximately the same for all systems of distribution, regardless of voltage, frequency or phase. Even in high-tension transmission lines the same methods may be used, there being no actual losses introduced by inductive drops. Most high-tension lines, however, have integrating wattmeters on both ends of the line. The difference in the readings will indicate the total loss in transmission. This loss may be easily subdivided into resistance losses and transformer losses.

Direct-current losses may be calculated in much the same manner as those of alternating-current circuits, although resistance losses and meter shunt losses are all that must be accounted for. We found the "drop of potential" method the most satisfactory for calculating the line losses, following along the same lines as described for alternating-current circuits (mentioned later). The meter shunt losses were taken care of in the same way as for alternating currents.

The different losses in an alternating-current system may be classified as follows:

Transformer iron losses
Primary resistance losses
Secondary resistance losses
Meter shunt losses

I will begin with the transformer iron losses, and show methods of calculating and keeping records of same. We have a card index system consisting of two sets of cards. One set has a card for each transformer on our lines and also those in stock, and shows the date of purchase, where set, manufacturer's

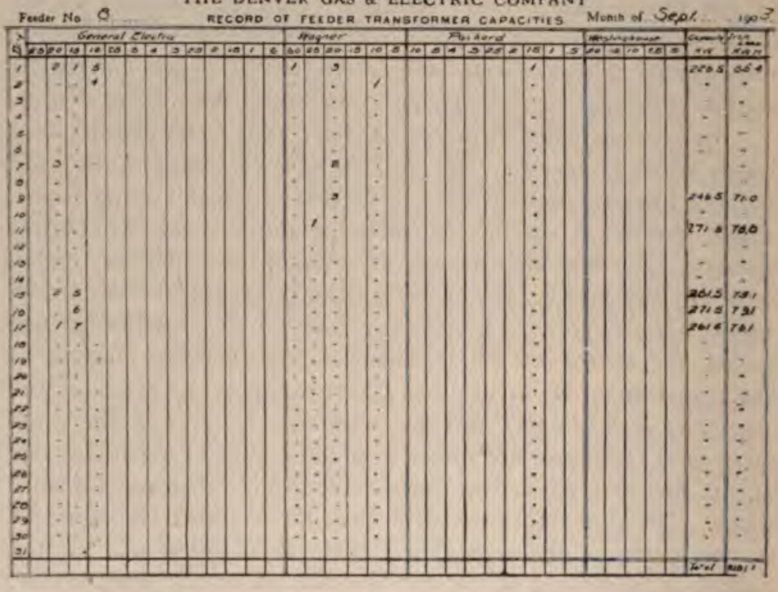
number and type, iron and copper losses as shown by test, and also whether or not the transformer has been removed and for what cause, as well as a retest on its iron loss before it is again placed in service. In fact, these cards show the entire history of each transformer from the date of purchase up to the present time. The other set of cards, which we will call the feeder index, shows the exact location, make and number of transformer, also the number of feeder on which it is located. These cards are arranged according to location and feeder, while the other index is arranged numerically according to the make and number of the transformer. Our records are not as complete as the above statement might seem to imply, due to the fact that these records have all been started within the past two years and do not include full data on transformers purchased prior to that time.

In a great many instances we have tested transformer iron losses while in service. We do this in a very unique way and without interruption to service. We have a small testing board, which includes a wattmeter, voltmeter and a small variable resistance. To these instruments are attached two flexible duplex cables of sufficient length to reach from the ground to any transformer on any pole. The primary fuses of the transformer are pulled, the neutral of the secondary is disconnected (that is, if the transformer is on a three-wire network), one side of the secondary is left intact and the other side is cut, and the wattmeter and resistance are inserted in the circuit by means of one of the flexible cables, the other cable being used for pressure wires. The secondaries are kept alive by the other transformers on the system. The resistance is then so adjusted that normal voltage is impressed across the secondaries of the transformer. Readings are then taken on the wattmeter, which indicates approximately the iron loss and may be corrected for instrument losses in the usual way.

We also keep up a transformer record sheet for the purpose of more readily finding our transformer iron losses as soon as possible after the first of the month. These sheets have a line for each day of the month, on which is placed the number of transformers of each size and make according to the different headings. On the extreme right of the sheet is a column for the total transformer iron loss for one day. This represents the total 24-hour loss on that particular feeder, which is the

summation of all the individual losses pertaining to the transformers on each line. At the end of the month this last column is totalized, and this represents the total loss for the month on that feeder. Figure 1 illustrates a typical sheet, which will more readily convey the exact idea of these transformer record sheets.

The next known loss to consider is the primary resistance loss. This loss has been more difficult to ascertain correctly and keep up from month to month than any of the other known losses.



THE DENVER GAS & ELECTRIC COMPANY

Feeder No. 8 RECORD OF FEEDER TRANSFORMER CAPACITIES Month of Sept. 1903

General Electric | Wagner | Packard | Westinghouse

Fig. 1

We have used four different methods of calculating this loss, and will take up each different method and endeavor to show the advantages and disadvantages of each.

The first method used was to measure up the length and size of wire in the primary feed, assuming one ampere to be flowing from the station to the first division point in the feeder, then assuming the current to divide proportionally to the connected load in each branch of the feeder; calculating and summing up all losses due to an initial flow of one ampere and using

that as a constant. Then amepere-meter readings are taken at short intervals at the station during a period of 24 hours. Each of these readings is then squared and multiplied by the constant. The summation of these losses will give the total primary resistance loss for one day. This method is fairly accurate, but is long and tedious and can not be relied upon any better than other more simple methods. One point of error in this method is the fact that a suspended wire stretches in course of time, making its cross-section smaller than it was originally and therefore of higher resistance. Joints and junction fuses also introduce errors of more or less magnitude. The results as obtained from this system are always considerably smaller than actual measured results.

I next undertook to accomplish the desired result by placing a recording voltmeter at the station and another at the centre of distribution and then taking the difference between the two readings and multiplying by the load in amperes corresponding to the drop in voltage, and summing up as in the previous method. This would be a very satisfactory method if this drop could be ascertained correctly. A small potential transformer is usually employed for the purpose of stepping the voltage down for the recording voltmeter. The ratio of these transformers, when used on a 2400-volt feeder, would be 20 to 1. These voltmeters can not be read with an accuracy closer than one volt; therefore it means an error which must be multiplied by a constant of 20, and when two voltmeters are used, one at the station and one at the centre of distribution, it means a possible multiplication of an error by a constant of 40. This error amounts to considerable where accuracy is essential.

The next method used was to place an integrating wattmeter in the primary lead just before it begins to feed, running pressure wires for it back to the centre of distribution. Readings were taken the first and last of the month, and kw-hour readings obtained subtracted from that obtained on the station wattmeter for the same period. This is a very good method, provided there are no grounds or individual taps taken off between the two wattmeters. If this should be the case, the results obtained might lead to an erroneous impression.

The method we finally adopted and now use exclusively is a measured resistance method. With the use of this method the

feeder must be shut down at some convenient time, preferably during light load, and the primary fuses of all transformers pulled; that is, all those on the station side of the centre of distribution. The primaries are then short-circuited at this point and the resistance of the circuit is measured by the "drop of potential" method with direct current, the direct current being supplied from a separate direct-current machine and the voltage varied so as to permit of a series of readings being taken. The loss is then calculated by means of ampere readings taken at the station at stated intervals, the same as in the first two methods. Or a better way than calculating each particular point is to calculate the losses for different amounts of current and plot a curve of watt loss and primary amperes. This curve also includes the primary copper loss of the transformer on the feeder, full load on the feeder being considered as the sum of the full-load capacities of the different transformers. The readings taken at the station may then be readily run off on this curve and summed up for a period of 24 hours, full-load copper loss of the transformers for the entire feeder being the sum of the individual losses for all transformers on the feeder. The copper losses of a transformer are assumed to be divided equally between the primary and secondary windings. This assumption has been borne out by tests. Figure 2 is a curve showing the different primary losses as calculated above.

After losses are obtained for a period of one day, the total loss for the month must be calculated. This is done by multiplying the output on the feeder for one day by the number of days in the month and dividing into the total output for the month as obtained on the feeder wattmeter. This result is squared and multiplied by the loss for one day and multiplied by the number of days in the month. These results will be as close as it is possible to calculate them and would be very accurate if it were not for the fact that the characteristics of the daily load curve change during the different seasons of the year. The peak is very sharp in the summer with a very small morning peak, while in the winter the peak is quite broad and the morning peak is much more noticeable. For this reason these losses must be recalculated from time to time during the year as these characteristics change. Figure 3 shows a curve of one of our principal business feeders illustrating these different characteristics. The

greater demand shown for March 29th is due to new business on that feeder. Evidence of new business is shown throughout the curve. Both December 18th and March 29th were clear days.

The kw-hours lost due to primary resistance for one year, multiplied by the actual cost of generation, will show whether reinforcements would pay financially and to what extent they might be carried. By cost of generation is meant the variable

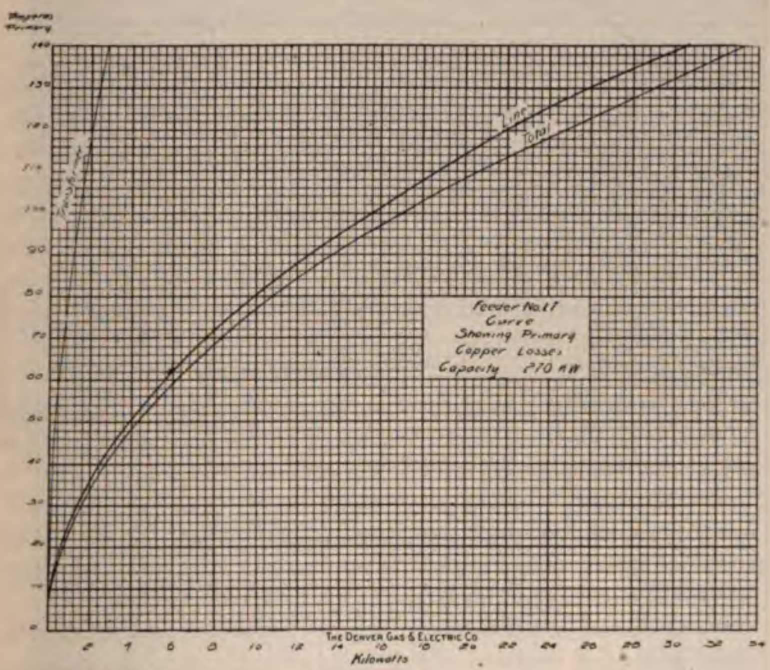
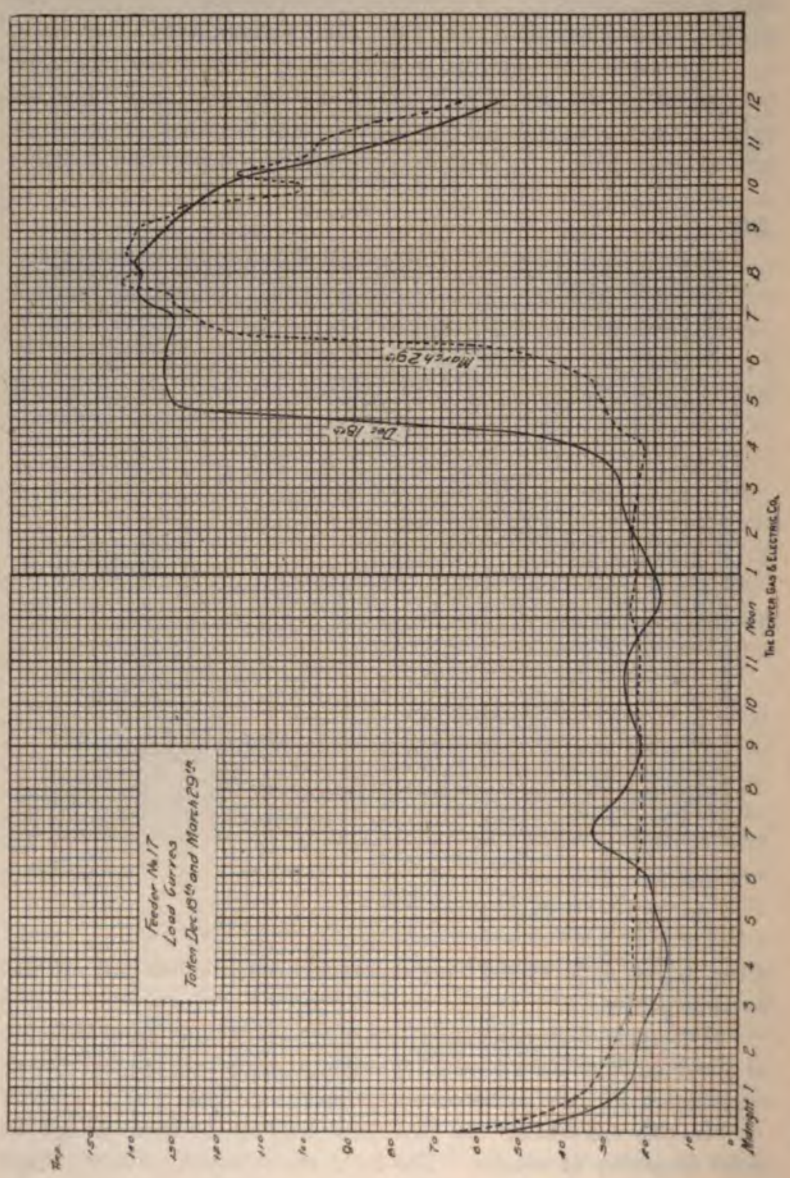


FIG. 2

costs, which vary as the output; it does not include any of the fixed expenses.

The secondary resistance losses are somewhat more difficult of accurate calculations. Following is the method we have used exclusively for our three-wire secondary network.

In this calculation we have had to assume some things in order to arrive at results. The total secondary load is assumed to be divided up in proportion to the sizes of the different transformers, one-half the load on each transformer to feed each way,



Feeder No. 17
Load Curves
Taken Dec 18th and March 29th
Dec 18th
March 29th
Amp.
Midnight
Noon
The Denver Gas & Electric Co.

FIG. 3

and this amount of current to feed one-fourth the distance between transformers. The assumptions have, however, been verified in each case by the testing of all transformers on the line. This assumption would not hold true, however, before we began to test our transformers systematically and place them on our lines in accordance with the actual load carried, instead of depending, as is the usual custom, upon the connected load. We found that the actual load carried varied very widely from that calculated on a basis of connected load.

With these assumptions and the size and length of secondary feeds being known, the losses may be figured for several different amounts of current flowing, and plotted in a curve. We also started in to figure the loss due to current flowing in the neutral, but this loss was found to be negligible on our system of distribution, due to the fact that our transformers are so evenly balanced that there is a minimum flow of current in the neutral. This is not the case on the majority of distributing systems, as most of the transformers are in the same condition as ours were before a systematic test was instituted by means of an instrument termed the "portable line meter." The instrument consists of an ammeter directly calibrated with a small series transformer having a two-piece iron core hinged together so as to permit of its being opened and clasped over a wire at any point. With this instrument we have been enabled to measure the exact load carried on a transformer at any time, also the amount of unbalancing. The loss in the neutral does not vary as the per cent of unbalancing and is therefore inappreciable for small amounts of unbalancing. But in most systems of distribution, where this unbalancing is quite considerable, it becomes an important item. Unbalancing not only increases the losses materially, but also decreases the available capacity of the transformer quite materially. It has been claimed that transformers banked together on a three-wire network would adjust themselves to the total unbalancing of the feeder. This is not true, as we have found transformers of the same make and size on adjoining poles considerably unbalanced on opposite sides; and even in cases where transformers are banked together on the same pole, they will not divide their loads evenly. This was very strikingly illustrated by an occurrence that took place here some time ago. During a breakdown in an isolated plant furnishing power for a theatre,

we were called upon to furnish them with light. In order to do this we placed six 10-kw transformers and one 20-kw transformer, all of the same make and type, just outside of the building and connected them up for 110 volts, tying them together with a 500,000-cm cable which fed the theatre. Following is the average load in amperes on each transformer during operation:

Size	Load in Amperes at 108 Volts
10-kw	106 amperes
10 "	93 "
10 "	130 "
10 "	112 "
10 "	90 "
10 "	90 "
20 "	158 "

I have also taken into consideration the resistance losses in the service loops. This is taken care of by assuming the secondary load to be equally divided between the different service loops, and taking the average length and size of a service.

The secondary transformer copper loss is taken into consideration in the same way as in the primary losses. A curve is then plotted of the secondary resistance loss, secondary transformer loss, and service resistance loss, and then a curve of the total losses is plotted. A sample of one of these curves (Figure 4) is here shown, watts loss being plotted against primary amperes.

The all-day losses are obtained in the same way as with the primary, using the station ampere readings in the same way; the station ammeter not being relied upon entirely, a standard portable instrument being cut in and used, and the switchboard meters being calibrated at the same time.

The only known loss now left to determine is the meter shunt loss, a loss that one might think at first hardly worth considering, but which is nevertheless of considerable importance and assumes very large proportions in some instances. The loss can be obtained with a greater accuracy and less trouble than any other of the losses. Each different type and size of meter must be tested and the average of a number of different tests taken. We use a meter record sheet for our meter losses on each feeder very similar to our transformer record sheets. These sheets are kept up from day to day, and at the end of the month the daily losses are summed up, giving the monthly losses. We

find it much easier to keep up our records in this way from day to day on the different feeders than it is to wait until the end of the month and then figure up the losses for the past month. It is also the most accurate, and the total losses may be ascertained much more quickly after the first of the month. A sample of one of these meter record sheets is here given (Figure 5).

Our total sales are figured up at the end of each month, and as meters are read in three different divisions at different times,

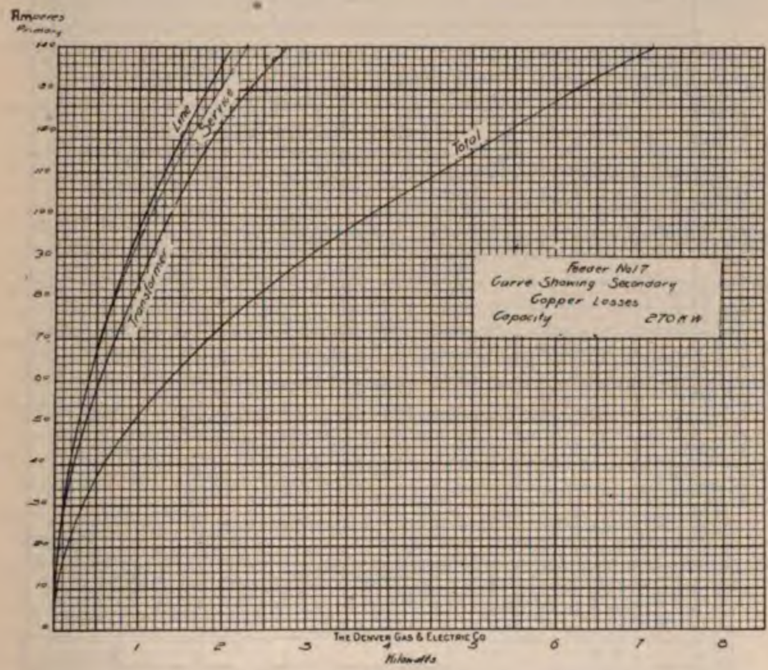


FIG. 4

the results do not exactly correspond to the monthly output. The bills for one-third of our consumers cover a period from the first of one month to the first of the next month, one-third from the 10th to the 10th, and one third from the 20th to the 20th. This variation might amount to considerable in one month, but, as we figure everything accumulative from month to month, our records are very accurate when figured over a space of several months.

I have now fully explained our methods for arriving at our known losses, and it will be interesting to note the results obtained in some of our feeders for the past year. We have 24 different

THE DENVER GAS & ELECTRIC COMPANY
RECORD OF METER SHUNT LOSSES Month of March 1904

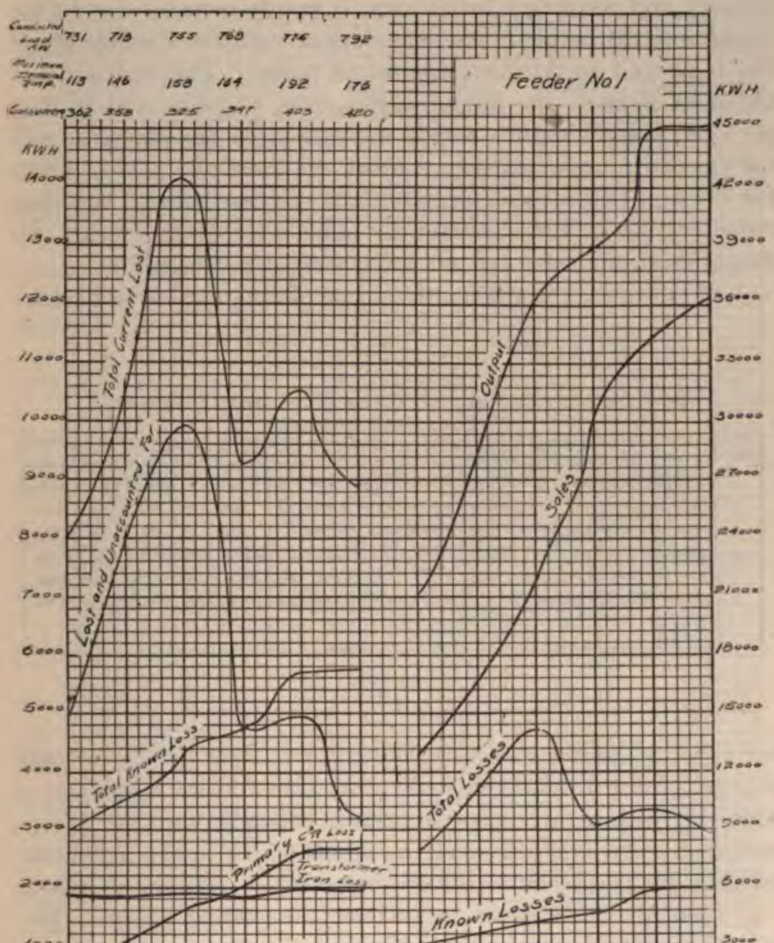
Feeder No. 20...

Day	Lamps +	Lamps −	Lamps Total	Consumers +	Consumers −	Consumers Total	Gen'l Elec. 10	Shunt Loss
1		30	11100		1	540	70	20.022
2	40	75	11065	1	2	539	69	19.974
3			11065			539	"	19.974
4	15	3	11095	2	1	540	70	20.022
5	60		11155	3		543	71	20.166
6			11155			543	"	20.166
7	35	10	11180	2	1	544	72	20.214
8			11180			544	"	20.214
9			11180			544	"	20.214
10	14		11192	2		546	72	20.310
11	96	14	11275	7	1	552	76	20.598
12	16		11291	1		553	76	20.646
13			11291			553	"	20.646
14	27	0	11310	3	1	555	76	20.742
15	40		11350	1		556	77	20.790
16	62	30	11382	1	1	556	"	20.790
17	24	36	11407	10	2	564	80	21.174
18			11407			564	"	21.174
19			11407			564	"	21.174
20			11407			564	"	21.174
21	10	10	11449	1	1	564	79	21.174
22	13		11462	1		565	"	21.222
23			11562			565	"	21.222
24	45	13	11595	3	1	567	80	21.310
25	2		11597	1		568	"	21.366
26			11597			568	"	21.366
27			11597			568	"	21.366
28	85		11682	2		570	81	21.402
29	24	12	11694	1	1	570	"	21.402
30	73	13	11754	2	1	571	82	21.510
31	30	10	11774	1	1	571	81	21.510
								645.162

FIG. 5

feeders, on all of which the above records are kept up from month to month. I have plotted graphically the losses on some of our feeders, showing variation of losses from month to month and

the gradual but steady decrease in the unknown losses. The first curve (Figure 6) is that of a residence feeder, which we



THE DENVER GAS & ELECTRIC CO.

FIG 6

designate as 1 West. It will be noticed that the output and sales have increased very rapidly. A slight hump will be noticed in

the output during October; this is due to some unknown loss, as the curve of sales does not show this characteristic, neither does the curve of known losses. It will be noticed that both the primary and secondary losses show a steady increase due to the increase in the output. The transformer iron loss remains about the same and so do the meter shunt losses. The relation that the sales show to the output varies from 59.3 per cent to 80.5 per cent, being almost a steady increase from beginning to end, the unknown loss increasing at about the same rate as the output for the first two months, dropping off the next month, and then remaining about the same for the remainder of the period, although both the sales and output increased considerably.

In table No. 1 is a tabulation of an alternating-current feeder

Feeder No 10
Table Showing Economy of Three-Wire over Individual Transformer System

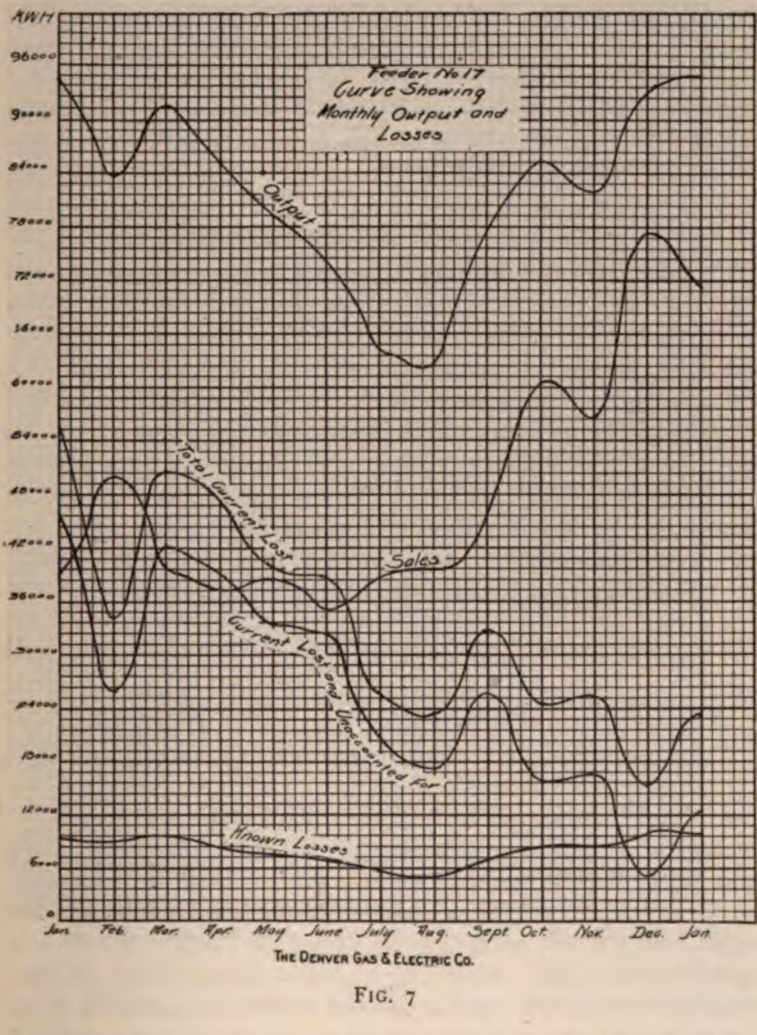
Month	Output	Sales	% of Output	Lost and Unaccounted For	% of Output	Transformer Iron Loss	% of Output	Primary C²R Loss	% of Output	Secondary C²R Loss	% of Output	Meter Shunt Loss	% of Output	Consumers
1	19250	7778	40.4	4877	25.4	5940	30.9	222	1.1	138	.7	295	1.6	273
2	15970	6630	41.5	2235	14.1	6475	40.6	229	1.4	92	.6	309	1.9	277
3	20042	10506	52.5	6140	30.6	2560	12.8	375	1.8	150	.7	313	1.6	281
4	35320	21166	60	9417	26.6	2390	6.7	1155	3.3	465	1.3	725	2.1	660
5	40140	28460	71.2	6421	16.1	2441	6.1	1440	3.6	560	1.5	770	1.8	692
6	40940	29113	71.2	6435	15.7	2425	5.9	1503	3.6	605	1.5	869	2.1	771

TABLE I

for a period of six months. During that time the feeder was changed from a 1000-volt individual transformer system to a 2000-volt with a three-wire secondary network, with the exception that there are still some instances where individual transformers are used, due to the sparsely settled territory it covers.

This tabulation shows several very interesting things. During the first two months the individual transformers were done away with and replaced with a three-wire network showing a reduction in transformer iron losses from 6475 kw-hours to 2560 kw-hours, a decrease of a little over 60 per cent. At the same time the lost and unaccounted-for has taken a jump of nearly 170 per cent. The output and sales increased considerably the same month, due to combining another feeder with this one, adding 387 consumers, which were changed over at the same

time to a three-wire distribution. In this instance we increased our sales to nearly double the original amount and decreased our transformer iron loss to about one-half the original amount. The



THE DENVER GAS & ELECTRIC CO.

FIG. 7

primary and secondary resistance losses were increased considerably, due to the increase in the output of the feeder.

A complete record sheet (table No. 2) is here shown of one of our principal business feeders, the same as is kept for all the

rest of our feeders. One of the interesting things on this feeder is that the watts per lamp of output remained about the same for the entire year, while the watts per lamp of sales increased

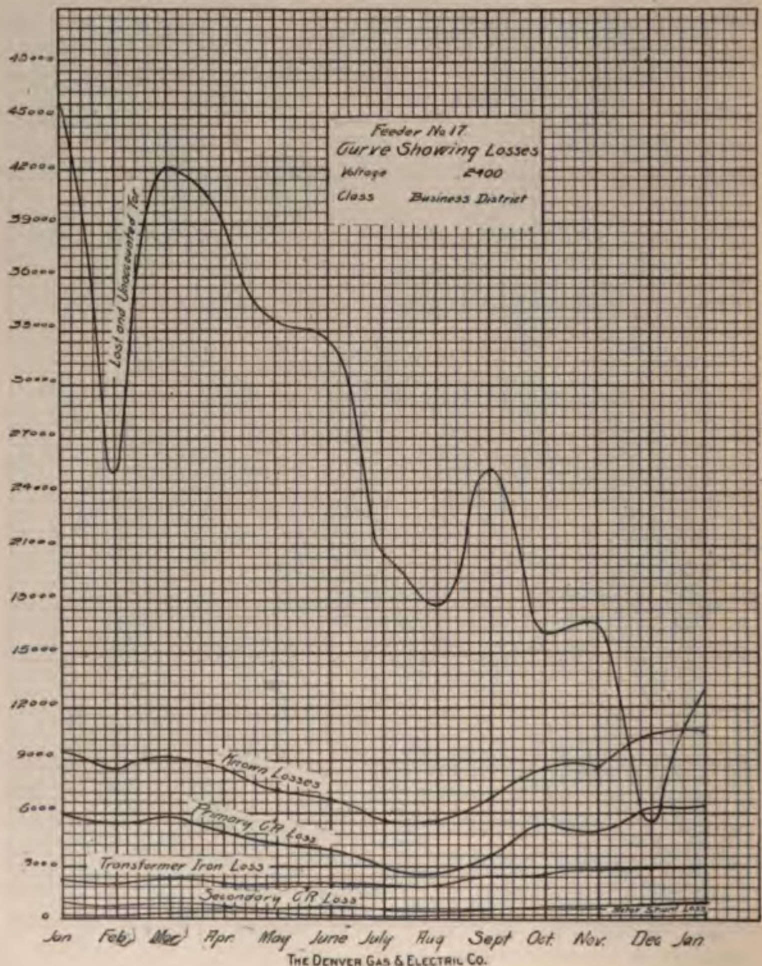


FIG. 3

during the same period to nearly double. The sales increased from 41.6 per cent to 83.5 per cent, the known losses remained about the same, while the unknown losses decreased from 48.4 per cent of output to only 5.22 per cent.

Our lost and unaccounted-for current has been systematically followed up and decreased very materially. This unknown loss is due to leakage through grounds, faulty meter registration, errors and theft. These losses have been plotted graphically as shown in Figures 7 and 8. Each circuit is tested for grounds, and when found these are traced down and removed.

The greater part of our lost and unaccounted-for current was found to be due to thefts. These were found by systematic inspection of service loops and interior wiring. Theft of current was found to be done usually by tampering with the wiring, removing pressure wires and jumping out meters, installing lamps ahead of the meter, and in some instances tampering with the meter so as to retard its rotation. Some of these things are very difficult to find, especially in cases of concealed wiring. Some cases of slow meters were found by placing a check meter on the secondary of a transformer feeding a three-wire district, making an isolated district of it by opening up the junction fuses on each side of the transformer. We have quite a number of ampere-hour meters on our circuits, which accounts for some of the lost and unaccounted-for, as an ampere-hour meter will not start on less than two to four 16-cp lamps. A check meter was placed on one district having nine ampere-hour meters and eleven integrating wattmeters. The results were as follows:

Registered on house meters	331.5	kw-hours	
Shunt loss on 11 meters	6.14	"	
Total	337.64	"	
Consumption as shown by check meter	367.3	"	
Loss	29.75	"	or 8.1 per cent

About the only absolute method of preventing theft of current, and as yet only adopted in isolated instances, is to place all meters on the pole. This could be accomplished in the business districts of the city by placing a number of meters in one box on a pole and running all services from this box and, where possible, bunching the wires in one cable. This would be especially advantageous where feeding a large number of consumers in a large business block, and where the running of such a cable would not be more objectionable than the present practice of 'bussing such a building. The principal advantage of such a system would be the impossiblity of stealing current from the

THE DENVER GAS AND ELECTRIC COMPANY.

Record of Current Made, Sold, and Lost. Feeder No 17.

MONTH	K. W. Hours Output	Output Accumulative	Watts per Lamp	K. W. Hours Sales	Sales Accumulative	Watts per Lamp	Per Cent Output	Total Known Losses	Accum. Known Losses	Watts per Lamp	Per Cent Output	Per Cent Sales	Cost Current Known Losses		Current Lost and Unaccounted for	Accum. Lost and Unacc'd for	Watts per Lamp	Per Cent Output	Per Cent Sales	Cost Current Lost and Unaccounted for		Total Current Lost	Accum. Total Current Lost	Watts per Lamp	Per Cent Output	Per Cent Sales	Cost of Total Current Lost		Cost of Current per Unit	
Jan	94184		11090	39142		4945	416	9477		1970	1008	242	131	20	45565		4760	484	1162	631	80	55420		4354	584	1410	763	00	01385	Jan
Feb	83664	177843	11300	49581	88723	6270	593	8567	18044	1080	1023	173	126	70	25516	71081	3230	305	514	376	80	34083	89185	4320	407	688	593	50	0140	Feb
March	91328	269170	11300	59910	128633	4940	437	9248	27292	1140	1012	232	148	80	48170	113251	5880	461	1225	678	70	41418	140443	5370	453	1230	827	50	016	March
Apr	84880	354058	10350	37361	165994	4580	440	8169	35461	1020	962	218	136	30	39330	152601	4630	464	1048	637	70	47519	188042	5840	560	1272	794	00	0167	Apr
May	79168	433224	9730	36225	204219	4700	484	7294	42755	897	922	191	126	20	33043	186250	4136	425	882	582	30	40943	229005	5030	516	1072	708	50	0173	May
June	74192	507416	9080	35014	239233	4300	472	6754	49509	827	911	193	115	20	32424	218674	3980	436	927	542	30	39178	268183	4800	528	1116	667	50	01700	June
July	64270	571692	7850	38422	277655	4700	597	5580	55196	683	87	1455	97	00	20266	238942	2470	316	527	351	50	25854	294031	3160	403	673	440	20	01737	July
Aug	62220	633912	7580	39600	317166	4620	636	5370	60473	656	866	130	91	40	17342	256284	2110	279	439	295	10	22720	316751	2770	366	516	386	50	017	Aug
Sept	77520	711432	11580	44755	361910	6675	576	6808	67281	1017	878	152	94	50	25957	282241	3870	335	580	359	00	32765	349522	4880	422	732	453	50	01387	Sept
Oct	85270	796702	10300	60507	422417	7320	711	8697	75878	1036	1007	142	112	80	16166	298407	1950	189	267	212	20	24763	374285	2990	291	410	325	00	01313	Oct
Nov	82100	878802	9820	56821	479238	6800	693	8558	84436	1025	1042	1500	120	70	16721	315128	2000	203	294	235	80	25279	399564	3000	307	444	356	30	01410	Nov
Dec	92800	971602	10300	77458	556696	8600	835	10025	94461	1113	10.8	1295	173	70	5317	320445	589	572	687	92	30	15342	414906	1705	16.5	198	266	00	01730	Dec
Total													1474	60						5002	30						6500			

MONTH	Trans. Iron Loss	Accum. Trans. Iron Loss	Watts per Lamp	Per Cent Output	Per Cent Sales	Primary Res. Loss	Accum. Primary Res. Loss	Watts per Lamp	Per Cent Output	Per Cent Sales	Secondary Res. Loss	Accum. Secondary Res. Loss	Watts per Lamp	Per Cent Output	Per Cent Sales	Meter Shunt Loss	Accum. Meter Shunt Loss	Watts per Lamp	Per Cent Output	Per Cent Sales	Equivalent 16 C. P. Connected	Connected Load K. W.	Maximum Demand	No. Transformers 5	10	20		Transformer Capacity	Per Ct. Trans. Capac. to Con. Load	Per Ct. Trans. Capac. to Max. Dem'd	Number Meters	
Jan	2273		288	242	482	6010		758	630	153	920		116	98	236	204		334	28	68	7917	506	225		10	6		220	435	970	234	Jan
Feb	2061	4334	261	247	410	5410	11420	653	647	123	858	1778	118	103	173	239	503	302	29	48	7909	506	230		10	6		200	435	951	237	Feb
March	2275	6610	282	249	570	5800	17220	710	636	145	890	2668	110	138	223	283	780	351	31	71	8074	517	260		10	6		200	426	847	253	March
Apr	1915	8526	233	227	5.2	5180	22408	674	612	1307	795	3463	97	194	212	279	1085	343	33	75	8144	522	250		9	5		190	364	764	250	Apr
May	1900	10505	244	251	5.0	4360	26768	558	55	114	608	4131	82	195	171	280	1361	351	36	76	8139	520	225		9	5		190	365	844	256	May
June	1915	12420	235	259	5.41	3955	30123	485	533	113	607	4738	74	182	173	277	1626	333	37	79	8163	522	220		9	5		190	364	864	250	June
July	1980	14400	242	308	5.16	2815	33538	351	447	748	442	5180	54	169	110	289	1917	354	45	75	8184	524	210		9	5		190	362	906	259	July
Aug	1980	16380	241	319	5.12	2695	36293	329	434	685	413	5593	51	166	100	290	2207	354	47	73	8209	525	205		9	5		190	362	921	260	Aug
Sept	2030	18610	303	314	543	3500	39833	352	459	738	546	6139	81	170	122	272	2479	405	35	61	6702	429	272	1	9	4		175	408	643	252	Sept
Oct	2450	21200	290	287	405	5065	44910	6.2	603	836	777	6916	94	191	128	345	2704	368	30	50	8287	530	275		9	4		170	341	610	274	Oct
Nov	2660	23920	318	324	468	4850	49768	581	591	863	744	7660	89	91	131	304	3085	364	37	54	8363	634	280		10	5		200	375	742	282	Nov
Dec	2749	26600	306	290	355	6080	55180	666	640	778	921	8501	108	99	119	335	3427	372	36	43	9016	577	293		11	8		270	468	907	301	Dec

TABLE II

light company. We should be getting paid for all current distributed and our losses would certainly be materially and permanently decreased.

I have now fully discussed all the principal items relative to the calculations of lost and unaccounted-for current. The importance of an analysis of the output of an electric station can be readily seen by the results given in this paper, and in the majority of instances such an analysis will show such startling results as will lead to investigations that will pay for the time and trouble many times over. A glance at table No. 2 under the column headed "Cost of Lost and Unaccounted-for Current" will readily show that a considerable amount of money can be spent toward decreasing the lost and unaccounted-for current. In no other way about a central station can money be spent more profitably.

DISCUSSION

MR. BURNETT: It would appear to me that the recommendation or suggestion on the lower part of page 175, to the effect that a number of meters be placed on a pole, is a bad one. I think it is only fair to assume that the majority of customers would object to having the meters where they can not be seen. Another difficulty would be that if they were placed on a pole any vibration caused by the wind might entail considerable creeping.

MR. PROUTT: I ask Mr. Humphrey how he arrives at the amount $5025.30, as being the value of the lost and unaccounted-for current? Was that the value of the coal required to produce the current, or the selling price?

MR. HUMPHREY: The actual cost of current distributed; all the variable costs that vary with the output, which include the cost of coal, oil, waste, and a part of station attendance; also the losses on the line.

MR. PROUTT: At what rate per kw-hour?

MR. HUMPHREY: That is shown in the last column, Table II; the average for the year being about one and one-half cents.

MR. PROUTT: About one and one-half cents? As I understand it, you figure the losses in the primary service from the volt and ampere readings?

MR. HUMPHREY: We figure the losses in the primary circuit by the C^2R method, using the station ampere read-

ings, corrected for power factor, and the resistance for that circuit, measured by the drop-of-potential method. The ampere readings are taken at intervals of fifteen minutes throughout the twenty-four hours.

MR. PROUTT: You have on the system primary wattmeters recording the entire output of the station?

MR. HUMPHREY: Yes.

MR. PROUTT: Comparing that with the current sold and the report from the customers' wattmeters, what would the loss be?

MR. HUMPHREY: The difference between the sales and output.

MR. PROUTT: The difference between the sales and output as recorded on the station instruments?

MR. HUMPHREY: That would be the total losses. That was 414,906 kw-hours per year.

MR. PROUTT: I desire the percentage.

MR. HUMPHREY: That is 42.5 per cent of the output for the year; but taking each month for the past year this percentage has been decreased from 58.4 to 16.5 per cent.

MR. MATLACK: I ask, if there is 10.8 per cent of losses accounted for, what is the percentage of sales accounted for and percentage of stolen current, or output, unaccounted for; how much of the revenue are they not getting?

MR. HUMPHREY: For the month of December the sales on this feeder amounted to 83.5 per cent of the output; the current lost or unaccounted for was 5.22 per cent, and the total lost and unaccounted for was 16.5 per cent.

MR. MATLACK: Assuming that the net earnings were found to be about 40 per cent of the gross earnings, if you had recovered the revenue for the stolen current or output unaccounted for your net earnings would have been increased about 25 per cent?

MR. HUMPHREY: Yes, sir.

(The meeting then adjourned until ten o'clock on Wednesday morning.)

ORDER OF BUSINESS

WEDNESDAY, May 25, 1904.

THIRD SESSION, 10 A. M.

1. Paper—"Economy in Minor Station Supplies." By EDGAR B. GREENE
2. Announcements
3. Paper—"Notes on the Internal-Combustion Engine as Applied to Central-Station Service." By E. E. ARNOLD
4. Paper—"Economy Test of a 5500-Horse-Power, Three-Cylinder, Compound Engine and Generator." By J. D. ANDREW and W. F. WELLS
5. Report—Committee for Investigation of the Steam Turbine. W. C. L. EGLIN, Chairman
6. Paper—"Practical Notes on the Steam Turbine." By FRANCIS HODGKINSON
7. Report—Committee on Award of Doherty Gold Medal. DR. SCHUYLER SKAATS WHEELER, Chairman
8. Discussion—Gas Engines and Steam Turbines
9. Paper—"The Mechanical Stoker and the Human Operator." By EDWIN YAWGER

THIRD SESSION

President Edgar called the meeting to order promptly at ten o'clock on Wednesday morning, and announced the first paper on the programme to be that on "Economy in Minor Station Supplies," by Mr. Edgar B. Greene, of Altoona, Pennsylvania.

Mr. Greene read the paper, which follows:

ECONOMY IN MINOR STATION SUPPLIES

Under this subject I propose to treat of stations of moderate size, or the small station rather than the large. Stations of moderate size, of necessity, do not have the number of people employed to separate the branches of work into classes, as can be done in the larger stations. Hence it is necessary to educate help to cover wider ranges of work than would be the case with the larger plants.

We have used with very good results a course of training that starts the young man as an apprentice either in the steam side of the plant or in the electrical side, giving him a thorough training through all branches of the work. Instead of the course covering a certain period of years, it covers the time necessary to develop the natural ability in the apprentice, that is, promoting the apprentice as fast as his ability will warrant the promotion, with the distinct understanding that each person must earn the promotion, and must have the ability to warrant promotion, or be required to stand aside for the next man; in other words, that each position in connection with the plant is filled by a person trained through all parts, and at no time is a man brought in from another plant located elsewhere and given a position over the men who have gone through the apprentice course. This plan, we have found, works very successfully, as it creates a feeling of assurance on the part of each employee that so long as he gives his best efforts to produce results he will not be required to stand aside for some other man who has not grown up with the plant. This does not mean that we exclude entirely, and will not bring in, new blood or new material, but it does mean that the new material is from time to time employed on some special parts of the work, but not retained and promoted; used rather to bring out a wider field or range of ideas.

We have had a number of our employees leave our employ after having finished the course and having been with us several years, spend two or three years with other concerns, and come back to our employ again. This has a tendency to bring in any good ideas being worked out elsewhere, and we are able to criticise our own methods by the experience thus gained, as well as to get in our employ again a man thoroughly trained in and familiar with our

methods of work; and in every instance of this kind we have found very satisfactory results.

We have had a number of our apprentices take a course with the well-known correspondence schools, and we can most heartily recommend this method of education.

With regard to station supplies, one item that we have found to be of value has been to standardize the fittings, valves and nipples of each diameter of pipe used in the plant; as an example, two-inch pipe would have two lengths of nipples, one a standard nipple, and the other a short nipple. A standard two-inch nipple would always be 15 inches long; if it were required to use a very short nipple, the short nipple of two-inch pipe would be four inches long; in three-inch pipe the standard nipple would be 18 inches long, and the short nipple six inches long. By just a little care in laying out the work it is easily arranged to follow out this system; then when repairs become necessary any nipple in stock will fit any place needed. The same is true in valves. We standardize by being careful to adopt a make of valve for the several sizes and do not buy anything else. This does not necessitate carrying so many extra parts, and if you have one extra value for each diameter you have a spare valve that will fit any place.

We have found that by putting Greenfield tubing inside of the steam hose (used for blowing off the soot in boiler tubes) the life of the steam hose is increased fourfold.

We have a home-made arrangement for bending tubes, such as are used in Stirling boilers, making segments that would be about two inches in thickness, and fitting about half of the circle of the diameter of the tube. These are made of cast iron and are bolted fast to a wide plank. We are able to heat and bend a straight tube to replace any tube that is defective. In the necessary repairs to Stirling boilers we do this by heating the tube in the fire under the boiler, which is kept quiet and clean at the time of heating; that is, the damper is closed on the particular boiler the tube is being heated in, and the fire burned down until it is perfectly clear on the top and has no green coal on.

For repairing the valve stems on engines, the valve stems in gate valves, and the renewal of the pins in engine governors, pumps and like machinery, we use standard cold-rolled steel shafting of the required size, cutting and threading this on the lathe in our little shop; this method makes our repairs to

engines and other machinery very simple and requires having the engines out of service but a very short time. For the renewal of the bushings in engine governors we get bronze tubing in standard size, then it is only necessary in most cases to cut a piece off the tubing to make a bushing; we use the same method for the valve motion for pumps and the different kinds of machinery in use, if the holes are not bushed. The first time repairs are necessary we ream these out to a standard size and bush with the above-described method. When next this part comes to be repaired it is a matter of only a few moments to renew the bushing and necessary pin.

It will be noticed that there is a strong disposition to follow up very carefully the details of all parts that have occasioned

FIG. 1

repairs and make a standard method fitting the several cases, so that in future repairs the work is very much simplified.

In a growing town there is a demand for ashes and cinders for use in buildings and in building permanent sidewalks. We have found it economical to arrange the ash pile so as to make it convenient for teamsters to load easily, thereby encouraging the carting away of the greatest amount possible of the ashes at no expense to the station. At some periods of the year there is no building of any account going on, therefore, no demand for ashes. We have devised a very economical elevator for loading the ashes then on cars, and they are taken away by the railroad company, free of any additional cost; they use the ashes for repairing sidings.

We find economy in buying strips of hard-rolled copper three-fourths inch wide, 12 inches long and .01 inch in thickness; we solder four of these strips together, making brushes for our arc machines. We find that this makes a very good brush and they are very economical. For the stiffener we use a phosphor bronze .026 inch in thickness of the same width and eight inches long.

We find very good results from an arrangement for draining all of the oil from engines by gravity directly to the oil-house,

Fig. 2

where it goes through the filters automatically without any handling except drawing off the water in the first tank. The filtering system in use is a very simple one; the oil coming from the engines goes directly to the bottom of a tank for the purpose of separating from the oil any water that may be in it; from the top of this tank it goes to the bottom of the second or settling tank; from the top of the settling tank it flows by gravity to the filters, two of which are kept in service. The oil flowing from the second or settling tank constantly and slowly is being filtered as fast as used; from there it goes to an under-

ground tank, and is pumped from this underground tank to an overhead tank for gravity distribution to the engines. The filtering material in use is simply a Turkish towel supported by fine brass woven wire. This we find gives us as good results as any method we have seen, and is very inexpensive, and very easily taken care of. The care necessary is simply shutting the oil during light load period from one filter, allowing it to drain, then renewing or washing the towel. This room is kept at a temperature of over 95 degrees and is practically underground, and the ventilation is just sufficient to allow such work as is necessary in the room.

We re-wind all defective coils for both multiple and series arc lamps, and all field coils for Thomson recording wattmeters, and re-wind all transformers.

It will be noticed that by doing the repair work as above described, one man is able to cover a wide field. While the person in this particular branch of work does not necessarily become an expert on each part, yet we find it profitable, taking all of these lines, to keep a man for the necessary repairing as above described, which covers also the machinists' work necessary.

INCLOSED-ARC LAMPS, BOTH MULTIPLE AND SERIES

The inner globes are brought to the station and washed with a revolving brush in a tank of water, rinsed in an adjoining apartment of the tank in clear water, kept approximately at 90 degrees, are dried in racks which support the globes from the inside, keeping each end free. They are then tested on a ground-steel plate for accuracy at the end for the inclosing cap, when they are fitted to their holders and the lower holder trimmed in the station. They are finally put in baskets arranged with a compartment for each inner globe and carried to their destination. We find it profitable to carry at least three days' use of inner globes in the wash-room in course of cleaning and drying; that is, globes that are washed on the 10th of the month would not be used prior to the 13th of the month. This allows globes to have 24 hours for drying and keeps two days' supply of globes fitted to the lower holder and supplied with the lower carbon; in any emergency this permits of sending out the second man trimming a circuit at once, instead of first preparing the inner globes before going out. Starting a new man trimming inclosed lamps, handling inner globes with

the necessary care and attention, it will be found that the average life of the inner globe would be about 800 lamp-hours for the first month; with careful training the average life on the second month will be found to be between 1400 and 1500 hours, and the arc lamp-hour per carbon will be found to be about 10 per cent shorter with a new man on the first month than the results which will follow after that period. This method we find gives us very satisfactory results with over 500 lamps in service. It is an exception rather than a rule to be called upon to send a repair man during the evening or night on account of a lamp out; and we find also an increased number of lamp-hours per trim. Carbons and globes are checked each day from the stock-room for the day's trim, and re-checked at the end of the month for the number gone out of stock; this gives an accurate account of the total amount, and is sure to include those carbons and globes which have been used in the repair-room.

In maintaining the system of poles, wires and fixtures we use a low wagon, wheels of about 32 and 34 inches high, with a flat top running out over the wheels; this gives a platform or bed (without side-boards) of about 6.5 feet wide and 20 feet long, and with this method two men can load a pole and such necessary tools for transporting to any part of the town.

We have found it very profitable to analyze carefully the orders for repairs, and where we find repairs necessary we aim to follow out the detail as carefully as possible, and where our workmanship is not as it should be, to improve it. Where any line of supplies used, either on the pole line or in the customers' premises, gives trouble sufficient to call attention to, we have found it very satisfactory to quit using such lines of material as give trouble on pole lines, and have the use of such material on inside work discontinued. We have been able in the last 10 years, by carefully following the details, to reduce our repair work about 80 per cent and give customers very satisfactory service.

In reading meters we find it works well in practice not to use one man, but to use several men from the several different classes of work. We do not send one man on the same route two months in succession, thereby making each man familiar with the locations of the meters on each of the several routes, and in the event of sickness we are never handicapped on account of meter-reading.

DISCUSSION

The President: I want to repeat practically the same statement made yesterday, because it will emphasize what I said yesterday. I said that more members had asked for Mr. Rhodes' paper than for any other paper. The same is practically true of Mr. Greene's paper. I have not a distinct recollection as to which of these papers was asked for by the greater number of our members, but practically the same number asked for each. As so many of our members expressed an interest in Mr. Greene's paper, we ought to have a very general discussion upon it.

Mr. Abbott: Mr. Greene's paper, while it has been handled from the standpoint of the smaller station, applies as much to the larger power-houses—particularly his method of selecting his employees and training them. I do not know of anything that will introduce discord into the operating force so promptly and so continuously as bringing in an employee and installing him in one of the higher positions in a power-house over those who have worked with the company for long years and have gradually earned their promotions. I have known of cases of men being brought in in this way and it produced a discord so violent that the only way in which to settle it was to clean out entirely the original force. Of course, if there should be another new man brought in later, he would have to clean out the second force and establish his friends in positions. I think it is very little credit to a company if it can not train up its own men as well as to have them come from the outside.

Regarding the matter of oil filtration, I have considered the function of the filter to be two-fold: one is to remove what grit there may be, if any, which there seldom is, and the other is to remove grease and water from the oil. This grease is formed by the saponification of the oil with the water, and it may be removed by settling or it may be removed by evaporating the water out of the grease. In the former case you lose the oil; in the second case you have the oil back again. By removing the water and the grease in a settling chamber, or by evaporating the grease, I find there is no need of a filtering material in the oil filter.

I wish to ask Mr. Greene what this Greenfield tube is of which he speaks; if it is something that will prolong the life

of the steam hose for four times its usual life, it is something we should know about.

MR. GREENE: The Greenfield tube is a product of the Sprague company. It is a flexible steel tube, somewhat similar to an English hose made of copper, and it is intended primarily for wiring purposes, such as conduits for wiring buildings. We have used the tube very successfully in connection with the steam hose in the boiler-house.

MR. ABBOTT: The inside and outside diameter?

MR. GREENE: A size that will go in the steam hose—just filling up the steam hose. I think it is one inch outside diameter and three-quarters inch inside diameter.

MR. ABBOTT: What steam pressure do you use?

MR. GREENE: One hundred and fifty pounds.

MR. M. A. MAXWELL (Easton, Pa.): The question of the life of inner globes interested me considerably. I have been wondering if the life of the inner globes obtained by Mr. Greene compares well with the average life as obtained by others. The city in which our company is located has a municipal lighting plant, but we light an adjacent town of 10,000 population with 101 arc lamps, series inclosed, 6.6-ampere. We have used on the circuit less than 70 inner globes per year covering a period of four years. They burn all night every night in the year. It makes the average life of the inner globe between 5000 and 6000 lamp-hours. I wonder if the life of 1500 lamp-hours is as good as is obtained by the average station. We have used less than 50 outer globes per year. Our company uses only 100 inner globes running over a year and a half, burning all night, and 50 per cent of the globes that are broken are broken by boys. It is a question whether or not our globes are better taken care of than in other places, and I should like some expressions on the life of inner globes from those who use them in larger quantities.

MR. GREENE: All the inner globes taken out of stock are charged against all lamp-hours, in our method. Every globe sent out is charged against the lamp, whether broken by boys, broken in the repair-room, or in handling.

MR. MAXWELL: So are ours. We took less than 70 globes for renewals for 101 lamps for the year. We may have better protection in our town.

MR. GREENE: Our boys may be worse than the boys in your city.

MR. ARTHUR WILLIAMS: I ask Mr. Greene what his practice is in reference to inclosed safety fuses, and if he carries them for parts of Nernst lamps?

MR. GREENE: We carry the standard Edison fuse plugs in stock for free renewals. We do not carry the inclosed fuse, or any repairs for the Nernst lamp.

THE PRESIDENT: If there is no further discussion on this paper, we will proceed to the next.

ANNOUNCEMENTS

THE PRESIDENT: Before proceeding, I should like to repeat some announcements made yesterday. This afternoon there will be a trip down the harbor and on the return a visit to the L street station of the Boston Edison company. At this station we expected to have a turbine installed, so that you could see the same in operation. The new turbine station is entirely completed with the exception of the turbine, and the turbine left Schenectady last week and is now on the road; but as many of you gentlemen came to Boston to see the turbine, we have made one for you. We have a full-sized machine, with all the auxiliary apparatus, in place. The gentlemen going there will see a full-sized turbine, the only difference between it and other turbines being that it is made of paper instead of steel. It is full size, and will give you an idea of the amount of space to be taken up in the station by the turbine when it is installed.

We want all the gentlemen who attended the convention held in this city in 1887 to give their names to Mr. Porter, the master of transportation. We shall try to get a photograph of them this afternoon. We shall have a photograph of the entire company; also a picture of these gentlemen taken separately.

The next paper in order is "Notes on the Internal-Combustion Engine as Applied to Central-Station Service," by Mr. E. E. Arnold, of Pittsburg, Pennsylvania.

Mr. Arnold presented the following paper:

NOTES ON THE INTERNAL-COMBUSTION ENGINE AS APPLIED TO CENTRAL-STATION SERVICE

The internal-combustion motor has been known to us for over a century in more or less limited powers and fields of usefulness, but the recent unprecedented activity of European engineers in the field of power production, brought about by the high cost of fuel and the smaller earning capacity of properties, has stimulated a corresponding activity in this country. As a result, the merits of the gas engine for all classes of service, and particularly for central-station work, are being thoroughly investigated by American engineers and power users in general. Although a subject of keenest interest at the present time, so many phases are presented for treatment in a paper of this kind that in the following pages only such will be touched upon as are of more direct interest to the users of central-station machinery.

It is generally recognized that the internal-combustion engine is the most efficient of heat motors, although the measure of its efficiency in comparison with that of other heat motors is not so thoroughly appreciated; nor has its extended development both at home and abroad produced among power users a confidence commensurate with the results obtained. In fact, the combustion engine has progressed to such a point that there now seems to be no reasonable limit either to its size or to its field of usefulness.

An explanation of the apparent indifference that has until lately prevailed in this country may be found in the location of the greatest centres of industrial development in close proximity to the natural fuel beds. For this reason the peculiar merits of the internal-combustion engine in the matter of fuel economy has not been brought home with such direct forcefulness. In Europe, on the other hand, and even in remote sections of this country where the cost of fuel is excessive, industries have, by force of necessity, turned from the steam engine to its more efficient rival in order to curtail operating expenses to the greatest possible extent. We

find therefore that, while relatively inconspicuous, the internal-combustion engine has now acquired quite extensive recognition, although the plants in operation are less significant for the immediate results attained than in the ultimate consequences of their own success.

In order to arrive at a proper conception of the present status of the combustion engine, we may properly refer to an excellent paper by Mr. Herbert A. Humphrey, read before the British Association, in Belfast, in 1902. Mr. Humphrey has compiled in a concise table the results of his inquiries among the principal builders of gas engines in Europe and America. This table did not take into consideration any engines under 200 horse-power in capacity, so that those quoted may be taken as representative of the modern high-power engine. At that time 327 engines, aggregating 182,000 horse-power, were either in operation or had been built, thus averaging over 550 horse-power per engine, and conservative estimates would now nearly double these figures. In the list a few engines of 1000 and 1500 horse-power were noted, the largest power developed in a single cylinder being about 600 horse-power, and several builders had engines of 3000 to 4000 horse-power under construction. It would therefore seem that this enormous development of the internal-combustion engine should induce in the immediate future great activity in the gas-power field, particularly in its relation to the generation and distribution of electricity; therefore the announcement that several of the builders of Europe and America were prepared to construct engines up to 6000 horse-power is not at all unexpected.

GENERAL TYPES

It has been taken for granted that the fundamental principles of heat conversion into useful work by combustion in a closed cylinder are quite generally understood, although the proposed working cycles of operation and mechanisms attendant thereto have been so numerous since the conception of the internal-combustion motor as to require some passing comment.

As in the evolution of all things, the development of the gas engine has again proven the law of the survival of the fittest, and we now find the battle being waged between the two modern forms of heat motor cycles, namely, the four-

stroke and the two-stroke cycle. The latter has its advantages and its adherents, but the former is decidedly in favor by reason of its greater simplicity and certainty of action. Both give a power diagram similar to Figure 1, comprising combustion, expansion and compression lines, the difference being in the manipulation of exhaust and admission.

It will be observed from the following table that the trend of modern gas-engine design is not only toward the four-stroke cycle, but unmistakably toward multi-cylinders and multi-cranks, with a further balance of favor on the side

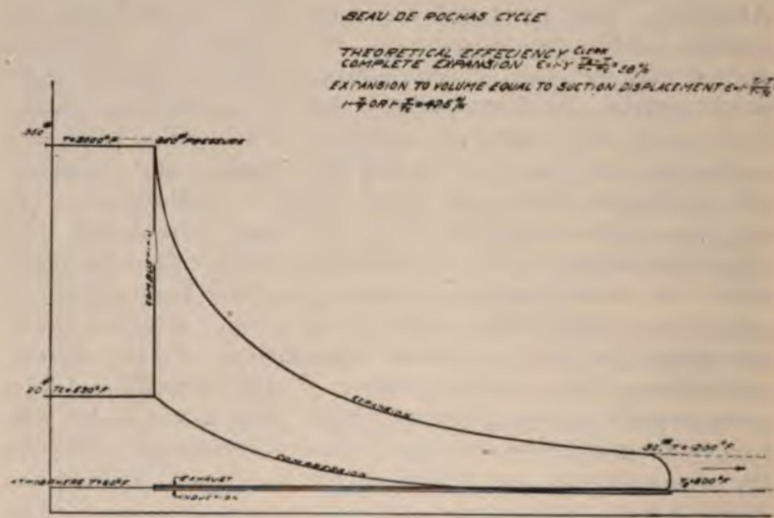


FIG 1

of engines employing the double-acting cylinder. Let us, therefore, glance briefly at the evolution from the elementary engine.

Figure 2 shows an elementary single-acting, four-cycle, single-cylinder gas engine. Starting with the piston just beginning its forward stroke, the mixture is ignited and the piston advances through the power stroke. Upon its return the exhaust valve opens and the burned gases are positively expelled. Upon its second forward stroke, the cylinder draws in a mixture of gas and air which upon its second return stroke is compressed to the desired degree. These operations

TABLE I

TYPES OF WELL-KNOWN GAS ENGINES BUILT IN SIZES 200-HP AND ABOVE. (MAXIMUM RATINGS GIVEN ARE LARGEST POWER UNITS THE MAKERS ARE REPORTED READY TO FURNISH)

Name	Cycle Type	No. Cyl'rs Sing. Act'g	No. Cyl'rs Doub. Act'g	Arrangement of Cylinders	Cranks No.	Cranks Angle	Rated Hp	Service
Cockerill....	4	1		Horz...............	1		200	Blowing
		2		" Tandem.....	1			Electric
			1	Horz.............	1		to	Blowing
			2	" Tandem....	1			Electric
			4	" Doub. Tand.	2	90	5000	"
Deutz.......	4	1		Horz	1		200	
		2		" Cross and Opposed..	1-2	0		Blowing
		4		" Double Opp.	1-2	180		Electric
			1	Horz..........	1			
			2	" Cross.......	2	180		"
Crossley.... (a)		1		Horz.............	1		200	
		2		" Opposed	1		to	Electric
		4		" Double Opp.	2	180	1000	"
Premier	4	1		Horz...............	1		200	
		2		" Tandem.....	1		to	Electric
		4		" Doub. Tand.	2	180	2000	"
Soest.......	4	1		Horz.			300	
		2		" Cross.......			1000	
Latombe....	4	1	1	Horz. Tandem....	1		500	Electric
Koerting.... (a)	2		1	Horz...............	1		200	Blowing
			2	" Cross........	2	90	2000	Electric
Nürnburg... (a)	4	1		Horz..............	1		200	
		2		" Cross Tand	1-2	0		Electric
			1	Horz.............	1		to	Blowing
			2	" Tandem.....	1			Electric
			4	" Doub. Tand.	2	90	6000	"
Oechel-hauser.	2	1		Horz.............	1		500	Blowing
		1		"	1		to	Electric
		2		" Cross......	2	180	2000	"
"Warren" Struthers, Wells & Co (a)	4	1		Vertical	1		250	
		2		"	2		500	
		4		"	4	180	1000	
Snow Pump Works... (a)	4	4		Horz.	2	180	1000	Pump'g
				" Tand. Opp..			4000	
Westing-house.. (a)	4	3		Vertical	3	120	300	Electric
			2	"	2	180	to	"
			2	Horz. Tandem.....	1			"
			4	" Doub. Tand.	2	90	6000	"

(a) Engines by American builders

may be followed out in the typical indicator card shown in Figure 1. It will be observed that there is one power stroke in every two revolutions.

In this elementary construction, piston-rod packing and

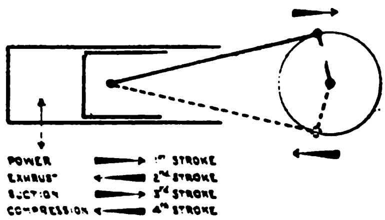


FIG. 2

cross-head may be dispensed with, and the cylinder is brought nearer to the shaft, thus securing utmost simplicity and compactness. In some cases of power application, how-

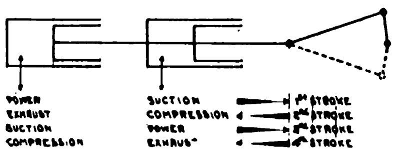


FIG. 3

ever, it is desirable to obtain a more uniform crank effort, which may be accomplished by using either multi-cylinder

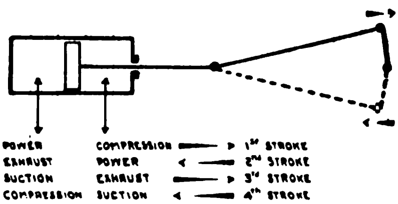


FIG. 4

combinations of single-acting cylinders or the latest application of the double-acting principles to gas-engine designs.

Figures 3 and 4 represent an elementary tandem, single-

acting engine and a double-acting engine. The gases pass through the same cycle of operation as in Figure 1. In these engines there are two power strokes in each two revolutions. The process may be carried still further, as in Figure 5, which represents a tandem-cylinder, double-acting engine. In this case there are two power strokes per revolution, as in the simple double-acting steam engine.

In engines employing a two-stroke cycle, it has been the endeavor of the designers to avoid the exhaust and suction stroke necessary in the four-cycle engine. This is accomplished in several ways, in one of which the piston at the end of its power stroke uncovers exhaust slots or ports in the sides of the cylinder. At the end of the expansion the exhaust gases are forcibly ejected through these ports, due to the remaining pressure. Whatever gases remain are at

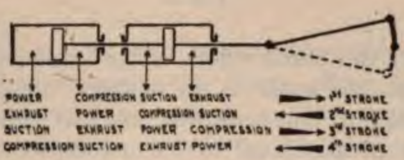


FIG. 5

atmospheric pressure and are finally expelled by a puff of air previously compressed by an auxiliary air pump.

Immediately following this entrance of air, a charge of gas, compressed by another auxiliary pump, is introduced into the cylinder and the whole is then compressed by the piston upon its return stroke. In this manner the functions of suction and exhaust strokes are delegated to auxiliary apparatus, although at the expense of considerable lost power and friction. The results obtained from two-cycle engines do not appear to be superior to those obtained through the use of the four-stroke cycle, and the sole advantage, if any, seems to be in the slightly greater compactness of design, which, however, is largely offset by greater complexity and cost of construction. The fact that the majority of builders of the largest engines in existence have adopted the simple four-stroke cycle in their designs rather indicates in which direction lies the balance of favor.

The effect of these various arrangements upon crank effort is shown in the following diagrams. These diagrams represent the crank effort and angular displacement curves for several arrangements of four-cycle gas-engine cylinders. Each of the curves is plotted for an engine having the same cylinder dimensions and speed of rotation. The vertical scale is in

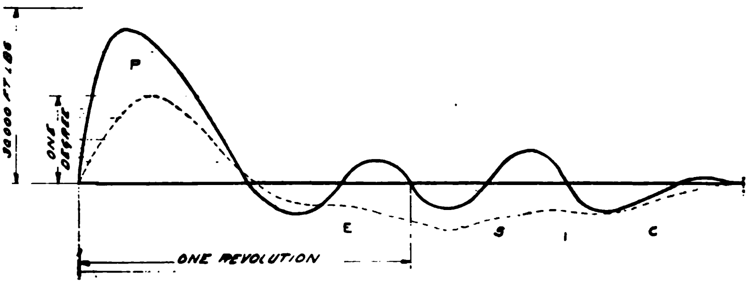


FIG. 6

foot-pounds for the crank effort curves, while for the angular variation curves the scale is in degrees displacement of the crank from that of true uniform angular rotation using fly-wheel capacity proportional to the horse-power developed.

Figure 6 corresponds to the single-cylinder, single-acting engine where the area (p) represents the power stroke, and

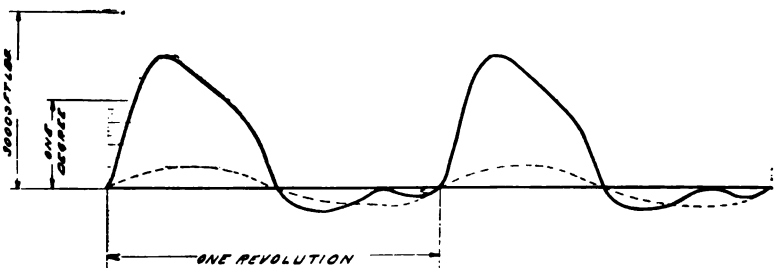


FIG. 7

the successive periods (e), (s) and (c) the exhaust, suction and compression strokes respectively.

Figure 7 refers to the tandem single-acting arrangement, while Figure 8 represents a single-cylinder, double-acting, four-cycle engine where two power areas occur instead of one as before.

Figure 9 represents a tandem-cylinder, double-acting, four-cycle engine where each stroke is a power stroke; this diagram also corresponds to a double-acting, two-cycle engine.

It is evident that the effect of more uniform crank effort will be progressively advantageous to the uniformity of rota-

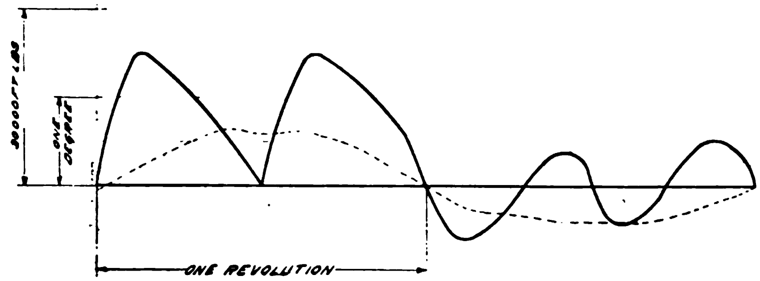


FIG. 8

tion of the engine. So with the double-tandem arrangement with cranks at 90 degrees, the crank effort diagram will be still further smoothed out, with a corresponding tendency toward uniform angular rotation. In each type flywheels would, of course, be used, proportioned so as to keep the cyclic variation in speed from uniform rotation within some

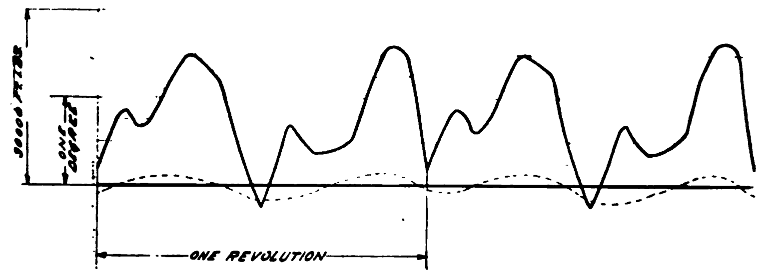


FIG. 9

predetermined limit. It is apparent, however, that the use of heavy flywheels should be considered as a last resource in obtaining low cyclic speed variations, which should rather be secured through the use of multiple cylinders as furnishing the most practical means of obtaining the uniform crank effort desired.

It should be borne in mind that the thrust transmitted from the piston, due to the pressure generated by combustion, forms but one of the factors making up the sum total of crank effort, and it often occurs that the inertia of reciprocating parts, further influenced by the angularity of the connecting rod at certain points of the stroke, largely counterbalances the effect of the piston thrust, so that the pressures actually transmitted to the crank pins are greatly modified

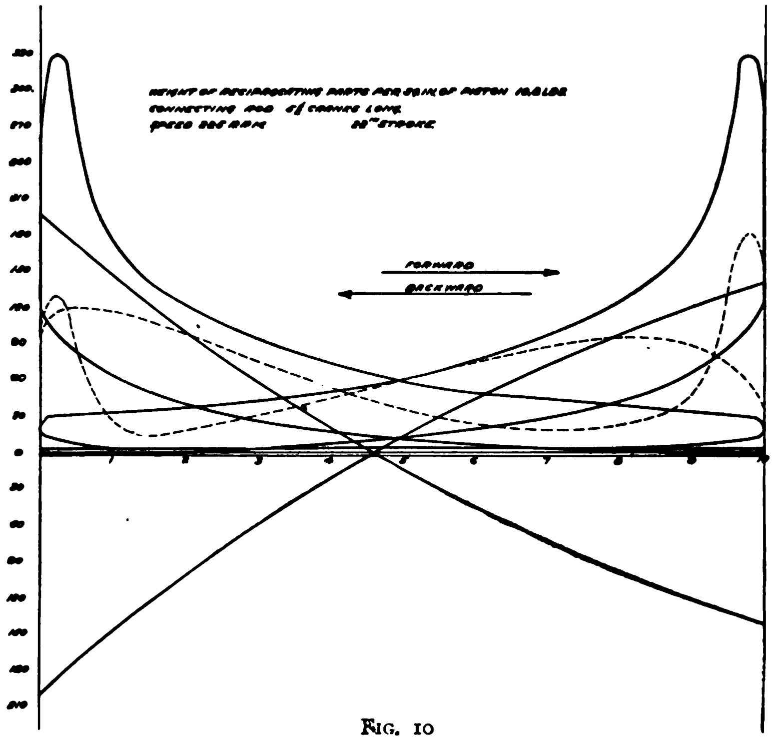


FIG. 10

from those shown in the indicator diagram. This is clearly shown in Figure 10, where these several factors have been worked out for an engine of the type corresponding to the diagram shown in Figure 9. It will be noted from this that the inertia effects are practically all absorbed by the compression occurring at each stroke, thus making a very smooth-running engine.

In this connection are involved the various methods of regulation. By far the simplest and most universally used

is the plain throttling governor. By this method, with a given gas, a uniform quality of mixture is maintained at all loads which will give the maximum efficiency. Speed regulation is obtained by a governor of the centrifugal type actuating a valve that proportions the quantity of mixture admitted to the load upon the engine. It should be borne in mind that the term "throttling" is not here used with the same significance as in the steam engine, in which the throttling of steam results in largely decreased efficiency.

Another method that has received considerable attention from designers is that of "impoverishing the charge" of mixture. In this method a constant quantity of air is always admitted to the cylinder, with a varying quantity of gas according to the load. It is evident, therefore, that maximum efficiency may be obtained from the cycle at only one load, while at all other loads the mixture is either too lean or too rich.

In the majority of small engines up to 50-hp the "hit-and-miss" method of governing is used. This is accomplished in various ways, the end sought being to proportion the *number* of power strokes to the load upon the engine and not their *intensity*. For instance, when the load is light, the governor enables the engine to miss one or more power strokes, and mixture is not again admitted until the speed of the engine has fallen slightly below the normal. For power work on a large scale, where close regulation is desirable, such as driving electric generators, this method is evidently unsuited.

A method of governing, which now appears to be in the ascendency for engines of large capacity for driving generators and other machinery requiring close regulation and high economy, is that employing a cut-off gear similar in many details to that used in various forms of poppet-valve steam engines.

FUEL GAS

Several distinct fuel gases suitable for gas-engine use are available. When reduced to calorific values per cubic foot of explosive mixture of proper constituency, the calorific ratings are, however, nearly equal.

This is shown by the last column in the accompanying table, which gives the chemical constituents, thermal equivalents and air required for theoretical combustion of the various gases ordinarily available for gas-engine work.

TABLE II

TYPICAL ANALYSES*

	H_2	CH_4	CO	C_2H_4 Illuminants	CO_2	N_2	O_2	B. T. U. Cubic Ft.	O_2 for Combustion	Air for Combustion	B. T. U. in 1 Cubic Ft. Explosive Mixture
Coal or bench gas......	46.00	40.00	6.00	5.00	.50	2.00	.5	646	1.21	6.05	91.7
Water gas............	48.00	2.00	38.00		6.00	5.50	.5	295	.47	2.35	88.0
Prod'r gas; hard coal...	20.00		25.00		5.00	49.50	.5	144	.225	1.12	68.0
Prod'r gas; soft coal ...	10 00	3.00	23.00	.50	5.00	58.00	.5	144	.24	1.20	65.5
Producer gas; coke.....	10.00		29.00		4.50	56.00	.5	125	.195	.98	63.0
Carburetted water gas .	40.00	25.00	19.00	8.50	3.00	4.00	.5	575	1.05	5.25	92.0
Coke oven gas.........	50.00	36.00	6.00	4.00	1.50	2.00	.5	603	1.12	5.60	91.0
Blast furnace gas	1.00		27.50		11.50	60.00		91	.143	.72	53.0
Natural gas; Pittsburg.	3.00	92.00		3.00		2.00		978	1.945	9.73	91.0
Oil gas...............	32.00	48.00		16.00		3.00	.5	846	1.615	8.07	93.0

*A. M Gow, *Electric Club Journal*, March, 1904.

The power to be developed by an engine of given proportions does not, therefore, vary within appreciable limits, except on producer gas and blast-furnace gases, when larger engines are required, or larger cylinders on the same engine frame. The rate of combustion is, however, fortunately less rapid with these than with other gases, due to the large amount of inert gases such as N and CO_2 present in the mixture. The compression may therefore be carried much higher without risk of pre-ignition or "back-firing," thus increasing the efficiency of the cycle. With water gas, the high percentage of hydrogen occasions quicker combustion and higher flame temperatures with so considerable a tendency to pre-ignition that this gas is not well adapted to gas-engine work.

Producer gas at present offers the greatest possibilities in the field of power for general utilization, due to its comparative cheapness, simplicity of generation and high efficiency. A comparison of the approximate thermal efficiencies of the various gas processes gives the following results:

Coal gas (without coke)	24 per cent
" (coke included)	60 "
Water gas	60 "
" (special quick-blast)	75 to 80 "
Producer gas	80 to 85 "

The ordinary producer-gas equipment comprises three elementary functions: a *generator*, resembling, on a small scale, the ordinary blast-furnace; a *scrubber* for cooling and removing recrement from the gas; and a *small boiler*, usually placed in the path of the heated gases leaving the producer. This boiler supplies steam which is later more or less dissociated in the producer into its elements O and H.

A recently introduced process, developed by Dr. Ludwig Mond, yields producer gas and sulphate of ammonia as a by-product. A considerable amount of special ammonia-recovery apparatus is necessary, but the returns, it is stated, from the sale of the by-product, often cover the cost of the fuel.

Several by-product coke processes are also being actively exploited in this country which seem to promise good results, the object being to secure a high grade of metallurgical coke as the main product and distilled gas as a by-product for use in heating processes and for power purposes.

PERFORMANCE

The actual performance of the modern gas engine does not, of course, even approximate the theoretical, by reason of its inability to utilize the entire heat generated in combustion. As its upper limit of efficiency, however, is so much higher than in the case of the steam engine, its *net* efficiency, based on actual output, approaches the *theoretical* efficiency of the steam engine operating under ordinary conditions.

In order to show what average performance may be expected from the modern gas engine of reasonable size the following table has been prepared, which gives as concisely as possible the results on a large number of carefully conducted shop tests at East Pittsburg and elsewhere upon Westinghouse gas engines, ranging in size from 100 to 600 brake-horse-power. These tests were selected at random from the test records of the company, comprising nearly a thousand complete gas-engine tests, the only care being to have them representative of several types and sizes of engines manufactured.

It is the usual custom of steam-engine builders to rate and express the economy of their engines in terms of indicated horse-power. In the gas engine, by reason of the higher pressures and temperatures dealt with, it is not such an easy matter to determine accurately the indicated horse-power. For this reason, the results given in the accompanying table are based entirely upon brake or useful horse-power, thus eliminating all uncertainties incident to the indicated work. Indicator cards were of course taken at uniform intervals during the tests, but are used entirely to determine the accuracy of valve settings. In the majority of these tests, Pittsburg natural gas was used, ranging in effective heat value from 850 to 1050 B. T. Us. per cubic foot. On account of fluctuations, occurring at various times, calorimetric tests are made at more or less regular intervals, and whenever especially important tests are being run the calorimeter determinations are made coincidently. The consumption of gas shown varies within certain limits, but when reduced to a basis of British thermal units per brake-horse-power, the results are more uniform.

A typical engine test is graphically represented in the form of curves, as in Figure 11, which shows a complete efficiency test upon a 175-horse-power vertical three cylinder

TABLE III

PERFORMANCE OF WESTINGHOUSE GAS ENGINES

BRAKE TESTS—EAST PITTSBURG

Engine: Size	Engine: Type	Test No	Calorific Value Gas B. T. U. p. r Cu. Ft. 62 F. 30 in. Kg.	Results: Overload B hp	Overload Cu. Ft	Full Load B hp	Full Load Cu. Ft.	Full Load B.T.U.	Half Load B.hp	Half Load Cu. Ft.	Remarks: Engines Operating	Remarks: Service
18 x 22	3-Cyl. Vert. Sing. Act'g	268	(Pbg. Nat.) 975	312	11.00	276.0	11.00	10,700	138.5	14.60	Long Branch Gas and Electric Co., Long Branch, N. J.	Electric light
16 x 18	"	714	880	197	10.90	178.0	11.30	9,950	90.0	14.90	"	"
14 x 18	"	619	905	203	10.30	176.0	11.80	9,800	90.0	13.75	Keystone Bank Building, Pittsburg, Pa.	Electric power
13 x 14	"	591	875	144	11.80	125.0	11.75	10,300	64.3	15.3	R. D. Nuttall, Pittsburg, Pa.	"
13 x 14	"	436	945	148	10.20	123.5	10.50	9,920	61.1	13.3	Union Switch and Signal Co., Swissvale, Pa.	"
25 x 30	"	E111	1000 (high)	606	10.01	553.1	10.45	10,450	37.5	13.40	Westinghouse Elec. and Mfg. Co., East Pittsburg, Pa.	"
15 x 22	"	663	960	254	10.10	219.0	10.50	10,008	112.0	15.00	Bradford Elec. Lt. Co., Bradford, Pa.	Elec. lt. & power
18 x 22	"	621	950	320	10.60	280.	10.90	10,350	142.7	14.70	Riter-Conley, Leetsdale, Pa.	"
11 x 12	"	662	860	96.1	11.40	85.7	11.40	9,800	43.8	14.10	Pittsburg Plate Glass Co., Ford City, Pa.	Pump'g water
18 x 22	"	299	1050	336	9.80	283.0	9.60	10,100	143.5	13.00	Madison Gas and Elec. Co., Madison, Wis.	Electric railw'y
18 x 22	"	790	850	311	12.40	285.0	12.50	10,600	146.0	15.90	Philadelphia High Press. Pumping Station, Philadelphia, Pa.	Fire
14½ x 22	Horz. Doub. Tand.	845	870	293	12.10	251.0	12.10	10,500	128.5	15.10		
		850		289	11.75	251.0	11.8	·0,260	130.0	15.10	Atlantic Rfg. Co., Phila, Pa.	Electric power & light
15 x 22	3-Cyl. Vert. Sing. Act'g	E415	93.4			150.0	116.	11,000			East Pittsburg Gas Works.	Power
"	"	415	133	Producer Gas		154.0	81.2	10,800			"	"
"	"	415	150			193.0	72.6	10,900			"	"

engine of the four-cycle, single-acting type, appearing in the table above as No. 619. It will be observed that the curve of total gas consumption is nearly a straight line. The curve of gas used per brake-horse-power differs somewhat from the corresponding curves of steam consumption in a steam engine inasmuch as they indicate progressively lower consumption up to the ultimate capacity of the engine. In these tests natural gas was used, averaging 990 total, or 905 effective, British thermal units per cubic foot. At full load the heat consumption was approximately 9800 B. T. Us. per brake-horse-

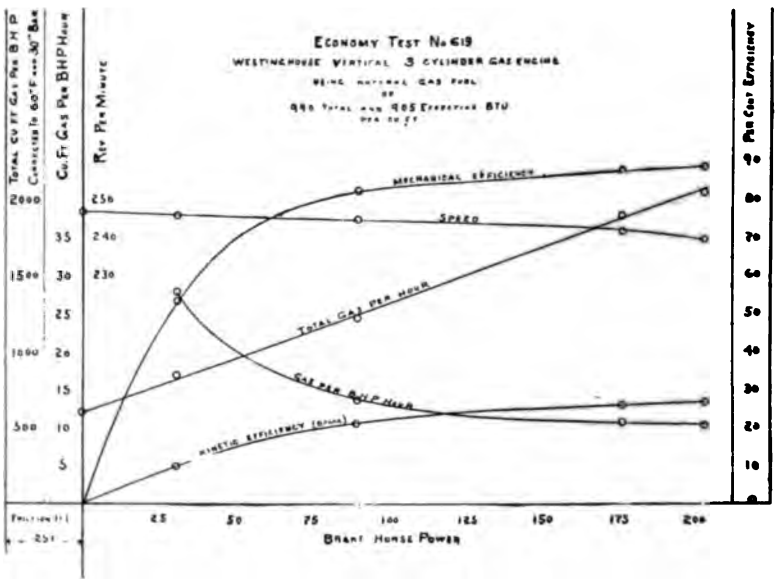


FIG. 11

power-hour. The gas consumed was 10.8 cubic feet. The mechanical efficiency of the engine at full load is approximately 87 per cent, and the useful or kinetic efficiency, based upon the above figures, is about 26 per cent.

In other fuel gases of different calorific value, the heat consumption per horse-power is approximately the same as above, but the quantity of gas varies nearly in inverse proportion to their heat values, as will be observed by reference to the last three tests upon different grades of producer gas.

In the usual form of gas engine, the expansion is not

carried down to atmosphere, as this would necessitate entirely too bulky construction in proportion to the extra power to be derived. The terminal pressure usually reaches about 30 pounds, which reduces the limit of theoretical efficiency (noted on Figure 1) to about 50 per cent, over half of which is actually obtained at the engine shaft. The losses comprise mechanical friction, heat discharged into the exhaust, and heat carried away in the cylinder-jacket water.

It is, however, possible to reclaim some of this lost heat, thus increasing the total efficiency of the outfit. In several instances the hot-jacket water is sent through radiators for heating the power building and offices; in others it is circulated through the water seal in gas holders to prevent freezing in winter; in still other plants, tubular boilers have been installed in the exhaust line from the engine through which the hot-water jacket water circulates, absorbing further heat from the exhaust gases, and is finally used as feed water in an auxiliary steam plant. Thus, in one case the total efficiency of the gas-engine equipment was increased from 25 to 65 per cent.* Again, steam may be raised to a suitable pressure for blowing the producers.

It may be held that the performance of engines tested under highly favorable conditions in the shop is not reproduced in actual practice where the machinery is obliged to operate under less favorable conditions, both as regards load and care received. As a matter of fact, however, the good performance on the testing floor is readily secured in actual service by properly-designed engines unless they are subjected to gross misusage by careless attendants, as occasionally occurs.

The numerical coincidence of one pound of coal expended in producing one useful horse-power has been long looked upon as the probable limit of steam-engine efficiency. It is therefore of particular interest that this result has already been attained by high-grade internal-combustion engines. The average efficiency of a producer-gas plant may be taken at 80 per cent, which is a conservative figure; many producers reach a higher efficiency. Assuming the calorific value of medium-grade coal as 13,000 British thermal units per pound, the heat delivered to the engine in the form of gas is 10,400

*C. H Williams, Madison Gas and Electric Company.

B. T. Us. As has already been shown in the preceding table on brake tests, this figure represents approximately the duty of the engines under consideration. It may therefore be expected that a gas-power plant properly designed and equipped will show a performance of about one pound of coal per brake-horse-power on full load.

At fractional loads the coal consumption would naturally increase, but not so rapidly as might be expected. Tests by different authorities upon gas-engine plants fully confirm the above.

Mr. H. A. Humphrey gives a two and one-half hour test upon a 75-kw gas-engine unit operating at full load upon Mond gas with a consumption of .92 pound of cheap slack coal per indicated horse-power-hour. During two years' continuous running of this power plant, the average coal consumption at the switchboard was 1.82 pounds per kw-hour, equivalent to 1.05 pounds per indicated horse-power-hour.

An interesting comparison between steam and gas equipments may be found in two electric power stations operated by an American concern: one covers a steam station of 1250-i.hp capacity; the other a gas station of 685-b.hp capacity. Both plants operate from 15 to 18 hours per day, and the steam plant runs condensing with a slightly higher load factor than the gas plant. Results obtained upon these two plants covering a period of five to six months' operation show that the heat consumption of the steam station was about 92,000 B. T. Us. per kilowatt and the gas station 29,100 B. T. Us. per kw-hour, or approximately one-third that of the steam-engine equipment.

In another instance, a 500-horse-power steam plant, equipped with non-condensing engines and boilers fired by natural gas, was superseded by an 800-horse-power gas-engine plant. During a 24-hour test at favorable load, the steam equipment required 86 cubic feet, and the gas-engine equipment 21.5 cubic feet of natural gas per kw-hour at the switchboard.

It may be of interest to carry this comparison a little further, into the domain of cost of equipment, with a view of determining whether investment in a gas-power plant will ultimately prove more profitable than in a steam plant of corresponding capacity. In order to establish a legitimate basis of comparison, it is necessary to consider two factors:

First, operating conditions and the cost of labor and supplies (except fuel) must be brought to a parity; second, the proper deductions for excess fixed charges, if any, must be made from the total saving recorded in the gas plant over the steam plant.

Assume, now, two plants each of 2000-kw capacity, one a steam station running on four pounds of coal per kw-hour, and the other a gas station requiring two pounds of coal per kw-hour, with an average output of 400 kilowatts or 20 per cent load factor, fuel costing $3.00 per ton delivered for each

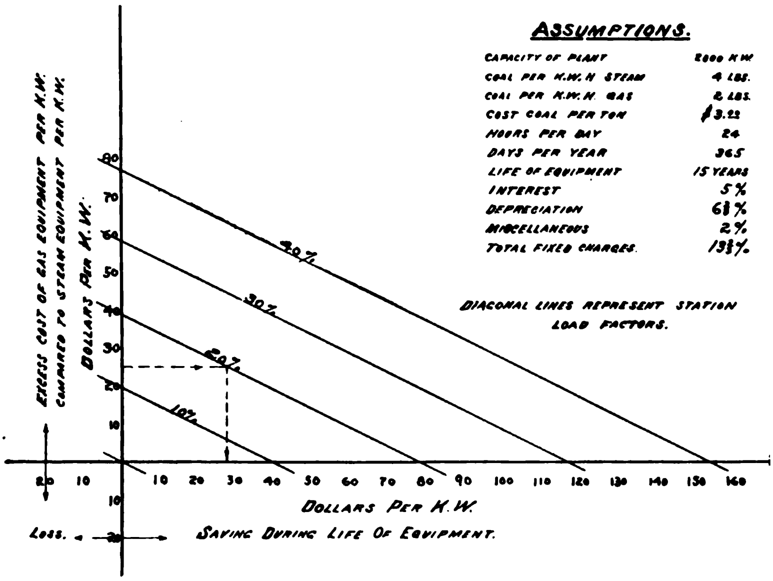


FIG. 12

plant. The saving in fuel cost due to the gas station throughout its life, which we assume as 15 years, amounts to $79 per kilowatt. This represents the gross difference in fuel cost with no fixed charges deducted. If, for instance, the two plants cost $100 and $125 per kilowatt, respectively, the difference in total fixed charges in 15 years of operation amounts to $51 per kilowatt. Deducting this from the total saving in fuel cost recorded in favor of the gas plant, we have in round numbers $28 per kilowatt, which represents the net saving we have in favor of the gas-engine equipment in

excess of the steam-engine equipment at the end of its life, or, by reference to Figure 12, it is seen that we could afford to pay $39 more per kilowatt for the gas-engine equipment and still be on a parity with the steam-engine equipment.

Consider another aspect of the case. A net saving of

TABLE IV

FIXED CHARGES

Cost of equipment	$200,000 00	$250,000 00
Interest, 5 per cent	10,000 00	12,500 00
Depreciation, 6⅔ per cent	13,320 00	16,650 00
Taxes, insurance, etc., 2 per cent	4,000 00	5,000 00
Total fixed charges	$27,320 00	$34,150 00
Excess gas over steam		$6,830 00
" " " " per kilowatt		3 42
" " " " " " 15 years		51 25

COMPARISON STEAM VS. GAS POWER FOR TYPICAL LIGHTING STATION

Assumptions	Steam	Gas
Capacity plant	2,000 kw	2,000 kw
Cost per kilowatt	$100 00	$125 00
Pounds coal per kw-hour	4	2
B. T. Us. per pound	13,000	13,000
Load factor	20%	20%
Hours operated per day	24	24
Days operated per year	365	365
Life of machinery	15 yrs.	15 yrs.
Interest	5%	5%
Depreciation	6⅔%	6⅔%
Taxes, insurance, etc	2%	2%
Cost coal delivered per ton	$3 00	$3 00
Computations		
Cost fuel per kw-hour	$0 006	$0 003
" " " day	57 60	28 80
" " " year	21,050 00	10,525 00

Saving gas over steam per year	$10,525 00
" " " " in 15 years	157,875 00
" per kw capacity " "	78 93
Excess in fixed charges gas over steam per kilowatt in 15 yrs.	51 23
Saving	$27 70

$28 per kilowatt at the end of the life of the equipment amounts to $56,000. Per year it amounts to $3724, which may be regarded either as revenue for increasing dividends or as interest upon increased working capital. At five per cent an

increase of $74,350 would be warranted. This fact is rarely appreciated by purchasers of power machinery, with whom initial cost is often the most important item, so that equipments of inferior quality and decidedly inferior economy are often installed rather than apparatus that in the long run will net a handsome revenue.

The high cost of the gas-engine equipment as given above is mainly chargeable to holder capacity. Without holders the cost will be much more nearly equal. Although gas engines are rather more expensive to build than steam engines, owing to the higher pressures carried, the larger number of expensive auxiliaries required in the steam plant raise the total costs nearly to an equality with the gas plant.

These figures are shown in graphical form in Figure 12 under the assumptions previously noted. The diagonal lines show the variation in saving due to load factor upon the station. In the above estimate, this load factor was assumed as 20 per cent, which is about that encountered in a typical lighting station where proper distribution of capacity among several generating units is made. With higher load factors, the capitalized saving would of course be greater, as is shown on the diagram for load factors of 30 and 40 per cent, likewise for a considerably lower load factor, than was assumed, for instance 10 per cent, the increased efficiency of the gas-engine plant can not overcome the increase in fixed charges, and a slight loss results under the latter assumption. With 30 per cent load factor, however, a corresponding saving of $66 per kilowatt is effected.

INSTALLATIONS

The results that have been obtained from the continued operation of gas-power plants may be of interest at this point as exemplifying the above facts regarding gas-engine economy. Its field of application has been extremely broad, embracing industrial works, central station, electric railway companies, high-pressure gas-distributing systems, pumping stations, etc., and although specific figures are in but few cases available, the general results indicate the high character of the service rendered.

A notable lighting and power plant is located at Bradford, Pennsylvania, operated by the Bradford Electric Light and Power Company, which, in 1898, converted their steam-

SHOP-TESTING OF VERTICAL GAS ENGINES

GAS-ENGINE-GENERATOR UNIT IN THE KEYSTONE BANK BUILDING, PITTSBURG

driven plant into a gas-engine plant, employing natural gas for fuel at a nominal cost of 10 cents per 1000 cubic feet, with a minimum contract of $3000 per year. The steam plant burned natural gas under the boilers and required 51 cubic feet per i.hp-hour, or about 86 feet per kw-hour. In the second year after the conversion from steam to gas engines, the cost for gas was reduced from over $9000 to the $3000 minimum, and at the end of four years after the conversion, although an increase of 30 per cent was recorded, the gas consumption of the station was still $3000 per year,

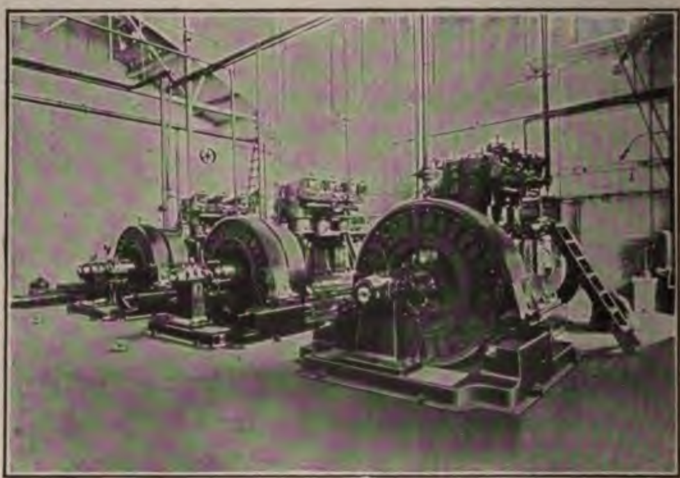
BRADFORD ELECTRIC LIGHT AND POWER COMPANY

and would have been less than $1700 per year had it not been for the previous contract stipulations. Observations upon the gas-engine station for a period of six months show an average consumption of 21.5 cubic feet of gas per kw-hour for all loads and conditions of operation. The gas is somewhat richer than Pittsburg natural gas, averaging about 1175 B. T. Us. per cubic foot. The cost of fuel, labor, supplies and repairs averaged $20,000 per year for the steam plant of 500 brake-horse-power, and $12,000 per year for the gas-engine plant of 800 brake-horse-power.

The Madison Gas and Electric Company is operating at

Madison, Wisconsin, a 700-horse-power gas-engine station, supplying power to the city railway system. The station is unique, in that fuel gas is furnished from the holders of an illuminating gas works operated in conjunction with the electric plant. A 1000-horse-power steam station also furnishes power for lighting and part of the railway system. Upon a basis of actual cost of gas in the holders, the gas-engine plant delivers a kilowatt-hour at the switchboard at a cost of fuel over one-third less than that required for running the steam plant. The cost of coal is the same for both plants; namely, $4.00 per ton.

Of more than ordinary interest to central-station engi-

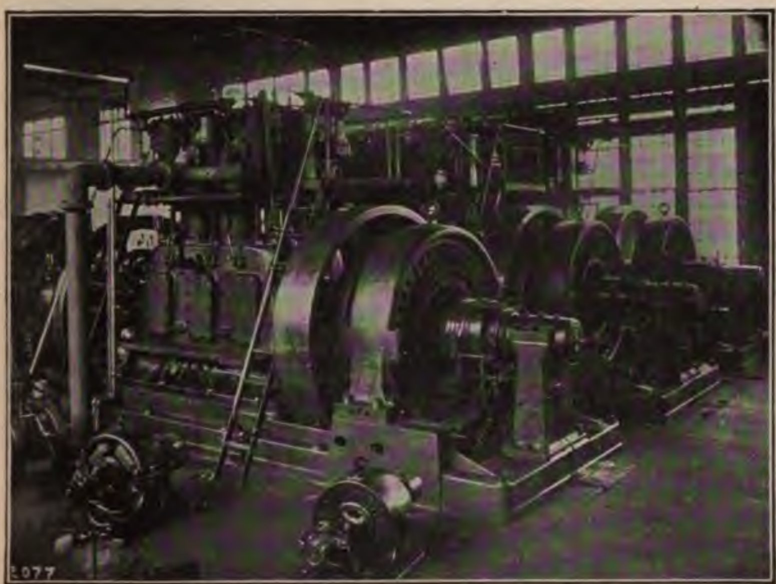


GAS-ENGINE-DRIVEN ALTERNATORS

neers is the operation of alternating-current generators driven by gas engines in parallel upon a common 'bus-bar. Until very recent years, this has been considered an impossibility, and, in fact, at the present time but few forms of gas engines are well adapted to do this work. Outside of the unquestionable success of several types of European engines in this service, it is of interest that a number of American plants are now in operation and are giving excellent daily service under these exacting conditions.

The Union Switch and Signal Company, at Swissvale,

Pennsylvania, operates its entire factory by polyphase induction motors supplied with current from a power station where four 125-horse-power direct-connected gas-engine alternator units are employed. The engines run on natural-gas fuel, and the variations in generating capacity to accommodate changes in motor load are secured by shifting loads between the several units, as in the case of alternating-current generators driven by steam engines. The gas-engine units are paralleled, operated and



GAS-ENGINE-DRIVEN ALTERNATORS OF THE WESTINGHOUSE MACHINE COMPANY

shut down in precisely the same manner as in steam-engine practice.

Similar equipments furnish power to the works of the R. D. Nuttall Company, the Westinghouse Machine Company and Westinghouse Electric and Manufacturing Company, of Pittsburg, the latter being a direct-current system. All manner of machine tools, shafting, cranes, elevators, as well as other appliances, are motor driven from the gas-engine plant, which furnishes current for lighting as well.

The Winchester Repeating Arms Company, of New Haven,

Connecticut, also employs electric power throughout its works. Direct-current machinery is, however, used. A producer-gas generating outfit was installed a few years ago for manufacturing purposes only, this being used in annealing ovens, forges, etc. One or two gas engines were installed on trial, others being added later, until the entire steam plant formerly in use was displaced by the gas-engine plant, with a large saving in fuel expense. Part of this saving was, of course, due to the increased efficiency of the electric transmission

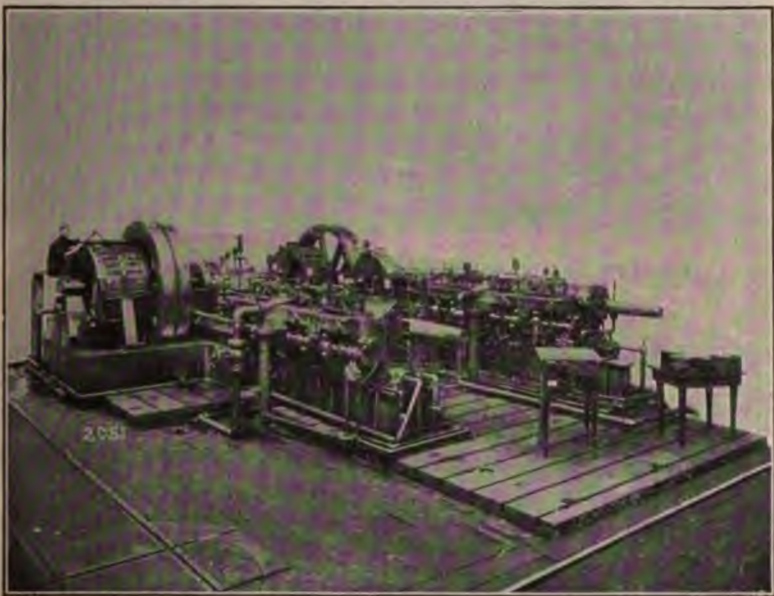
GAS-ENGINE-ALTERNATOR UNIT IN THE POWER PLANT OF THE ATLANTIC REFINING COMPANY, PHILADELPHIA

system, but mostly to the higher economy of the gas engines, as was apparent from the small increase in gas generation observed after the gas-engine plant had been put into service.

A 2000-horse-power alternating-current parallel-operated plant is just being placed in operation at Philadelphia by the Atlantic Refining Company. The engines are of the double-crank, double-acting, tandem-cylinder type and utilize by-product oil gas for fuel. The equipment furnishes light and power to the refinery at Point Breeze.

At San Luis Potosi, Mexico, two 200-horse-power horizontal, double-acting gas-engine units are in operation upon producer gas, the plant furnishing electric light and power to the city. These units are similarly arranged for parallel operation with polyphase engine-type generators.

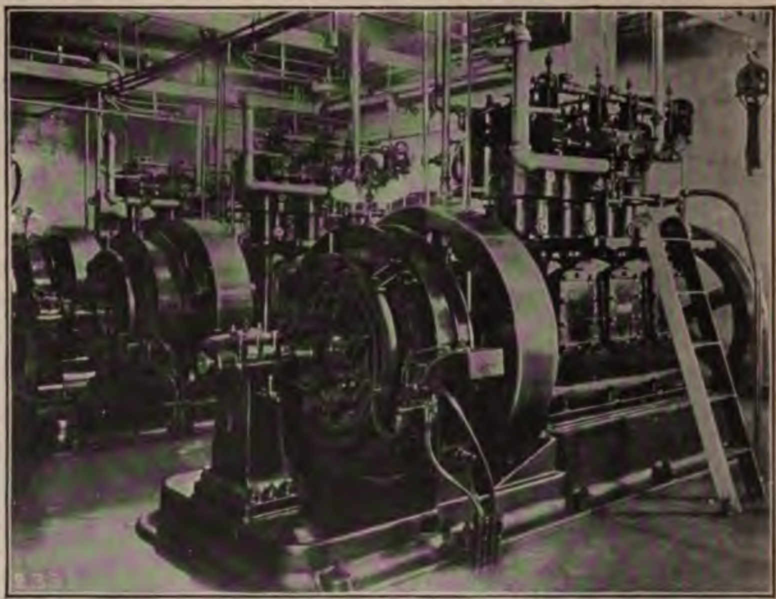
In South America, a number of producer-gas stations have just reached completion, the largest of which aggregates 2250-horse-power and operates the shops and yards of the Buenos Ayres Street Railway Company. The generating



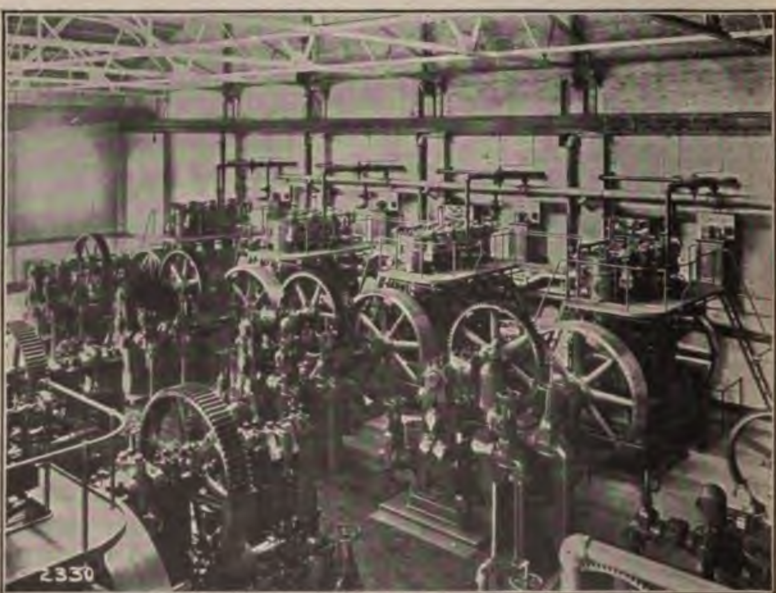
SHOP-TESTING HORIZONTAL GAS ENGINES

equipment is all of the polyphase engine type, furnishing arc and incandescent lights and motive power to the distributing system. A bituminous producer plant installed solely for this purpose supplies the gas engines with fuel gas.

These few instances will suffice to indicate in some manner the progress that is being made in this interesting field of power application; and it would seem evident that if the internal-combustion engine has shown itself suitable for the service demanded from large industrial works with their



LIGHTING PLANT OF THE UNITED GAS IMPROVEMENT COMPANY BUILDING, PHILADELPHIA



GAS-ENGINE PUMPING STATION OF THE PHILADELPHIA HIGH-PRESSURE FIRE STATION

excessively fluctuating loads, it should prove even better suited to the fulfillment of the more favorable conditions met with in central-station work. The experience already gained in this direction at least indicates that the difficulties formerly considered unsurmountable have now been fairly overcome, and that the gas engine may be no longer dismissed from commercial consideration.

THE PRESIDENT: We have three or four papers on kindred subjects this morning, and with your permission I am going to ask the gentlemen who are to take part in the discussion of these papers to wait until they have all been read and we will then have a general discussion of all of them at the same time. Pursuing that policy, we will have the paper on "Economy Test of a 5500-Horse-Power, Three-Cylinder, Compound Engine and Generator," by Messrs. J. D. Andrew and W. F. Wells, of New York.

The following paper was read by Mr. Andrew:

ECONOMY TEST OF A 5500-HORSE-POWER, THREE-CYLINDER, COMPOUND ENGINE AND GENERATOR

The engine whose economy is dealt with in this paper is located in the Waterside station of the New York Edison company, Thirty-eighth and Thirty-ninth streets and East River, New York city. It is one of the 11 engines built by the Westinghouse Machine Company for the New York Edison company, with a steam consumption guaranteed not to exceed twelve and a half pounds of dry steam per indicated horse-power per hour, when the engine is developing between 4900 and 5500 horse-power with 175 pounds steam pressure at the throttle, 27-inch vacuum at the low-pressure cylinder and turning 75 r.p.m.

The engine is of the three-cylinder, compound, vertical, double-acting type, with the high-pressure cylinder located between the two low-pressures. One low-pressure leads the high-pressure by 133 degrees, the other low-pressure following the high-pressure at 101 degrees, thus making the two low-pressures 126 degrees apart. The high-pressure cylinder is fitted with four-beat poppet valves, the head-end valves being in the head itself, the crank-end valves being in a valve chamber cast on the side of the lower head; which arrangement accounts for the difference in clearance given later. The steam valves are opened by releasing gear similar to that used in Corliss practice, the closing of the valves being accomplished with a multiple-leaf wagon spring, the action of which is controlled by an air cushion. The exhaust valves are opened by reciprocating cams and closed by multiple-leaf wagon springs, which compel them to follow back down the cam as it recedes, the curvature of the cam being such as to allow them to seat without shock. The low-pressure cylinders are fitted with double-ported Corliss valves in the heads. The steam valves are closed by vacuum dash-pots, the exhaust valves by positive motion. The steam and exhaust valves on all cylinders are operated by separate eccentrics. The low-pressure cylinders are provided with steam jackets, and the receiver between the high and low-pressure cylinders with a re-

heater. This receiver is 54 inches in diameter by 21 feet 10 inches long. The steam enters from the high-pressure cylinder through a 16-inch pipe at the centre into a space 34 inches long; here it divides, passing in either direction through a nest of reheater tubes having a total area of 1130 square feet of iron heating surface, then through two 24-inch pipes to the low-pressure cylinders. Each low-pressure cylinder has a 26-inch exhaust pipe leading to a surface condenser of 9200 square feet of tubular surface furnished by three-quarter-inch outside diameter, 18-gauge brass tubes.

The auxiliaries consist of a 32-inch horizontal, double-acting air pump, a 32-inch horizontal, double-acting circulating pump tandem to the air pump, both driven by a 16-inch horizontal, double-acting steam cylinder, the common stroke being 24 inches. The steam cylinder is fitted with a Corliss fixed cut-off valve gear and a throttling governor; separate eccentrics are used for driving the steam and exhaust valves. The steam used by the auxiliaries was not charged against the engine in the tests reported in this paper.

The dimensions of the engine measured hot were as follows:

High-pressure cylinder, diameter 43.98 inches; rod, diameter nine inches; stroke, five feet.

Two low-pressure cylinders, each diameter 75.65 inches; rod, diameter nine inches; stroke, 5 feet.

COMPUTED VOLUMETRIC CLEARANCES

High-pressure cylinder head end, 5.75 per cent; crank end, 15.10 per cent.

Average, 10.425 per cent.

Low-pressure cylinders head end, 4.21 per cent; crank end, 4.25 per cent.

Average, 4.225 per cent.

The ratio of the combined volume of the two low-pressure cylinders to the high-pressure cylinder is six to one.

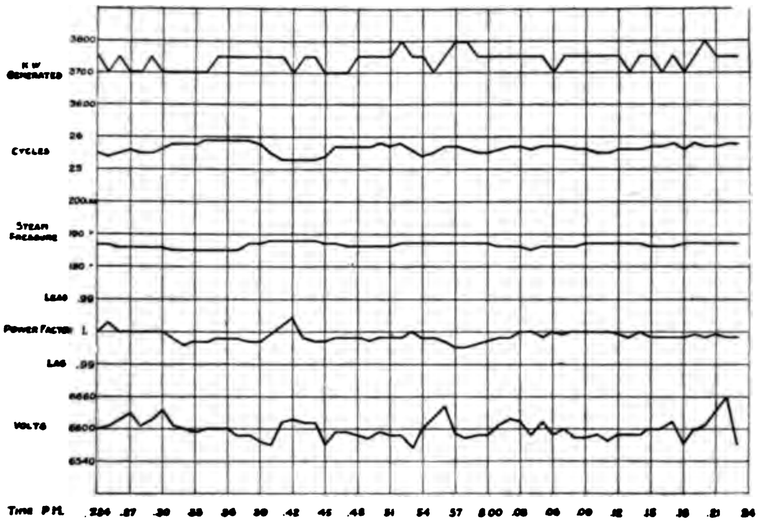
The engine is direct-connected to a three-phase, 40-pole, 25-cycle General Electric generator of the revolving-field type with a normal rating of 3500 kilowatts, or 307 amperes per phase at 6600 volts. This generator has an overload rating of 400 amperes per phase for three hours.

The primary object of the test being to confirm the engine builder's guarantee, J. M. Whitham, member of the American Society of Mechanical Engineers, was chosen as referee, and all engine testing was done under his supervision, and according to

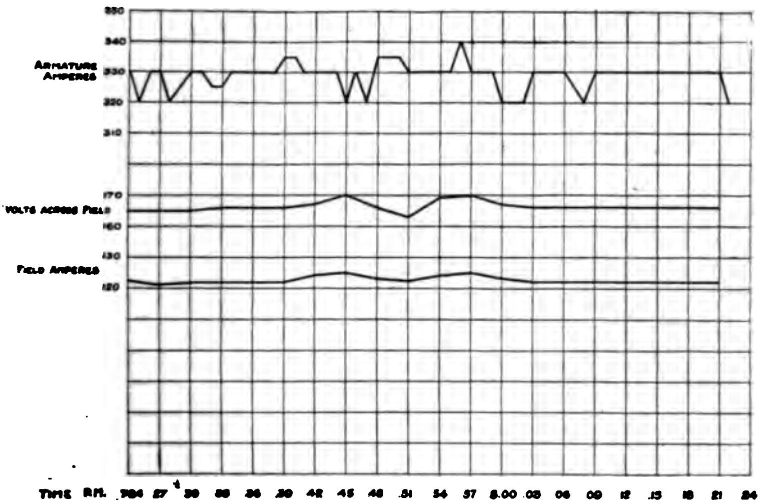
the code of the American Society of Mechanical Engineers. All the instruments were calibrated before and after the test and as nearly as possible under test conditions. All readings were taken at three-minute intervals by two independent observers. One indicator was used on each end of each cylinder and all indicator cards were worked out independently by each party to the test and then verified. The quality of the steam was determined by throttling calorimeter at the throttle and at the entrance to the low-pressure cylinders and by separating calorimeter at the high-pressure exhaust. The steam consumption was determined by weighing the water of condensation from the surface condenser, which was repeatedly tested and found tight. The weighing was done in two tanks mounted on platform scales, each handling between 3000 and 4000 pounds per charge. The condensation from the receiver, the reheater and the jackets, was weighed with separate tanks and scales. The vacuum was measured by two mercury columns, one at the outlet of each low-pressure cylinder.

During the tests, the generator was run in multiple with two or three other generators of the same type and capacity in regular service, supplying the Edison low-tension system through static transformers and rotary converters located in the substations. The load on the three phases was therefore practically balanced and the power factor was kept at unity by adjusting the fields of the rotary converters. The load on the generator under test was maintained practically constant by locking the engine governor in a fixed position, and then varying the speed of the system to compensate for the fluctuations of steam pressure, by manipulating the cut-off of the other engines working in parallel with the engine tested. In this way the variation in load was kept within about two per cent above or below the average. Curves Nos. 1 and 2 show the variation in the various readings for a typical hour.

Diagram 1 shows the connections of the instruments and transformers used during the test. Readings of alternating-current wattmeter, ammeter, voltmeter, power-factor indicator and frequency indicator were recorded every minute; and of the ammeter in the field circuit and the voltmeter across the field terminals every three minutes. An average was made of these readings for each hour of the tests and the results are shown on



CURVE No. 1



CURVE No. 2

data sheet No. 1. No readings were recorded of the potential of the field-charging 'bus, as it bears no fixed relation to the output of the generator. It, however, averaged about 250 volts.

A very careful check was made by the Lamp Testing Bureau

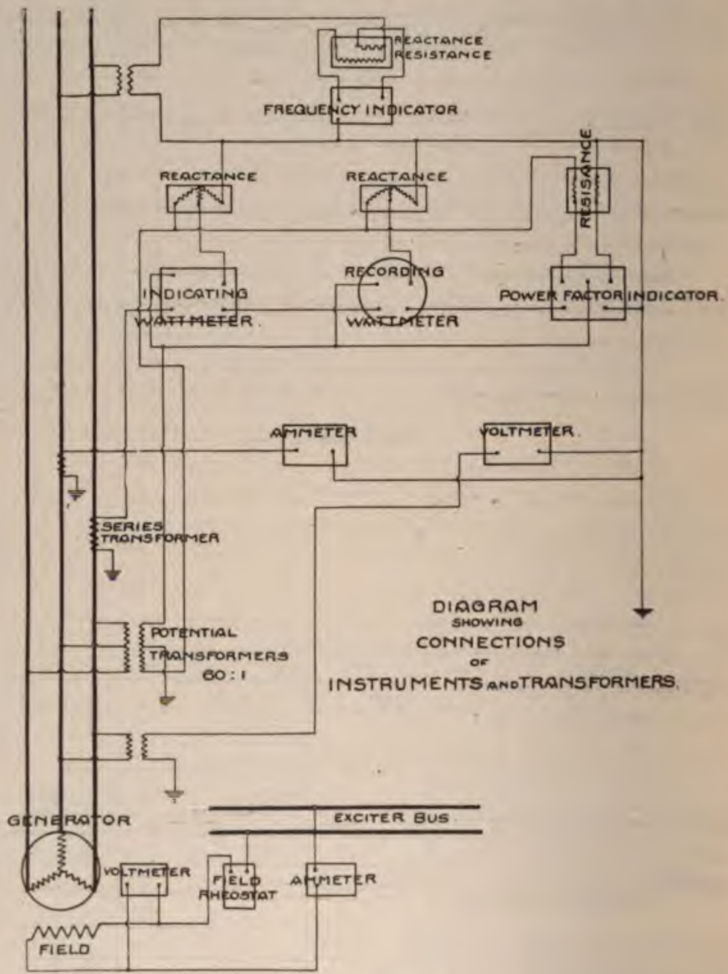
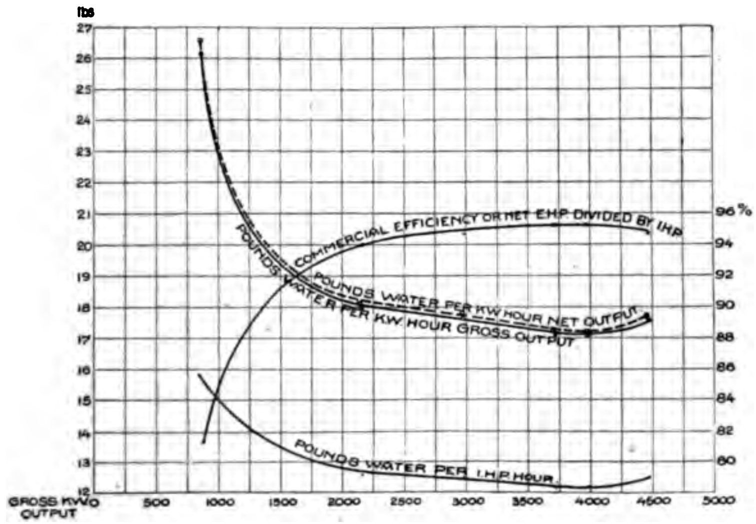


DIAGRAM No. 1

of the accuracy of the switchboard wattmeter used in the tests and of the series and potential transformers used in connection with it. This was done by comparing its reading with the sum

of the readings of two Weston wattmeters, one connected in each of two phases of the circuit. These Weston wattmeters were calibrated against primary standards, using a potentiometer, standard cell and standard manganin resistances. The Weston wattmeters were connected in the secondaries of independent series and potential transformers, the ratio of which were checked in the Bureau under similar conditions. The result of these checks indicated that any error in the switchboard wattmeter readings was within one-half of one per cent, which, considering the fluctuations of the load, was probably within the



CURVE NO. 3

errors of observation, and the instrument was considered as correct.

Curve No. 3 showing pounds of water per kw-hour, pounds water per i.hp-hour and the commercial efficiency of the unit at various loads, is plotted from the data given on data sheet No. 1. This curve shows that for outputs of from 2500 kilowatts to 4500 kilowatts the economy varies between 17.12 and 18 pounds of water per kw-hour of net output at the generator terminals. The commercial efficiency, or the net electrical horse-power divided by indicated horse-power, varies from 94.5 to 95.2. This range

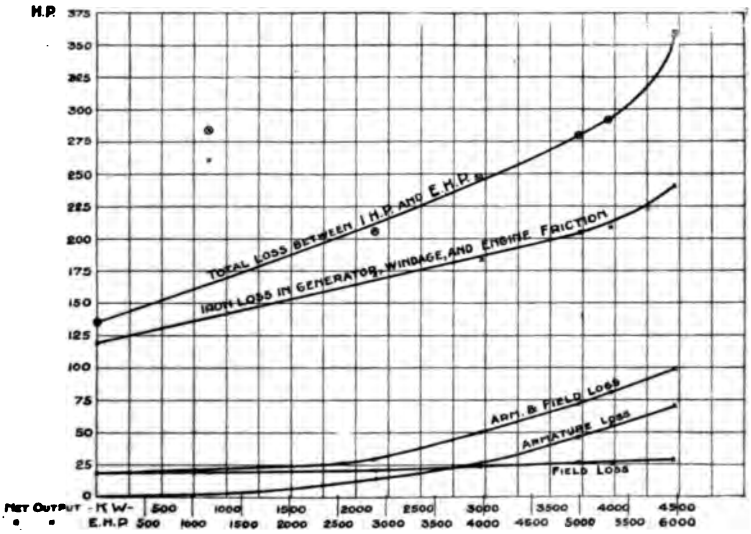
DATA SHEET No. 1

Average Efficiency Tests

Date	Feb. 2	Feb. 2	Feb. 2	Jan. 30	Jan. 30	Jan. 30	Jan. 30	Feb. 2	Feb. 2
Time	2.17 to 3.16	3.32 to 4.41	4.44 to 5.43	4.24 to 5.23	7.24 to 8.23	5.24 to 6.23	6.24 to 7.23	12.40 to 1.40	11.17 to 12.16
Average kilowatts, armature	867.	2166.	2981.	3737.	3730.	3740.	3746.	3970.	4483.
" indicated horse-power	1428.	3088.	4218.	5283.	5205.	5278.	5273	5598.	6326.
" steam pressure	193.6	187.	186.3	185.	182.4	183.	182.8	183.7	181.6
" receiver pressure	21.1	24.5	24.4	24.8	23.5	23.5	23.3	24.7	24.8
" vacuum	27.15	24.4	26.9	26.31	26.37	26.36	26.36	26.75	26.6
" cycles	25.6	25.44	25.43	25.41	25.64	25.45	25.59	25.55	24.92
" armature volts	6318.	6324.	6522.	6588.	6600.	6582.	6588.	6342.	6360.
" " amperes	......	......	263.4	327.4	328.7	327.8	329.1	362.3	408.9
" amperes in field	103.7	109.	118.	123.6	122.5	122.2	122.1	122.9	129.9
" volts at field terminals	133.	140.3	157.1	165.4	166.3	166.	165.3	161.	170.5
" kilowatts in field	13.8	15.3	18.5	20.4	20.3	20.3	20.2	19.8	22.1
" " net output at terminals	854.	2150.	2962.	3717.	3719.	3720.	3726.	3950.	4461.
" e.hp output at terminals	1144.	2882.	3971.	4983.	4985.	4986.	4994.	5307.	5980.
Total dry steam per hour	22,674	38,982	52,529	63,866	64,207	64,182	64,323	67,802	78,725
Pounds per indicated horse-power per hour	15.88	12.62	12.45	12.09	12.19	12.15	12.19	12.11	12.44
" " kw-hour—total output	26.14	17.94	17.61	17.09	17.17	17.14	17.16	17.03	17.55
" " " —net output	26.58	18.08	17.7	17.18	17.27	17.25	17.26	17.12	17.64
Efficiency, net e.hp ÷ i.hp	80.2%	93.4%	94.3%	94.4%	94.7%	94.4%	94.6%	94.8%	94.5%

covers all loads that the machines are called upon to carry in actual service.

The different factors which make up the loss between the indicated horse-power and the net electrical horse-power are shown by curve No. 4, plotted from the data given in data sheet No. 2. For the field and armature losses, measurements were made of the energy in the field circuit, amperes in the armature, and resistance of the armature at working temperature. From the total loss, or difference between the indicated horse-power and electrical horse-power, was subtracted the field and armature



CURVE NO. 4

losses, the remainder being the iron and windage losses in the generator and engine friction. The iron losses of the generator could not be measured separately, owing to the difficulty in getting accurate cards from the engine at such light loads. The apparent inaccuracy of the total loss shown at a load of 867 kilowatts, which also affects curve No. 3, is probably due to the extreme fluctuations of the load and inability to make accurate readings of the instruments.

Data sheet No. 3 gives information concerning 10 different

hourly tests, which were picked out as of most interest. The test referred to in column No. 1 is the one in which the best economy was obtained, 11.93 pounds of water per i.hp-hour, 16.78 pounds of water per kw-hour, 221 B. T. Us. per i.hp-minute, 309 B. T. Us. per kw-minute. Columns Nos. 2 and 3 show the behavior of the engine carrying normal load without receiver reheater or low-pressure jackets in service. Under these conditions, the steam consumption was 12.158 pounds of water per i.hp-hour, 17.10 pounds of water per kw-hour, and the heat consumption 223 B. T. Us. per i.hp-minute and 313 B. T. Us. per kw-minute in column No. 2, 12.196 pounds of water per i.hp-hour, 17.17 pounds of water per kw-hour, 224 B. T. Us.

DATA SHEET No. 2

Details of Losses

Net Output		I.hp	Total Loss Hp	Field Loss Hp	Armature Loss Hp	Field and Armature Losses Hp	Iron Loss Generator, Windage and Engine Friction Hp
Kw	E.hp						
0	0	118.6	135.4	16.8	0	16.8	118.6
854	1144	1428.	284.	18.5	2.5	21.	263.
2150	2882	3088.	206.	20.5	14.5	35.0	171.
2962	3971	4218.	247.	24.8	26.7	51.5	185.5
3726	4994	5273.	279.	27.1	45.2	72.3	206.7
3959	5307	5598.	291.	26.5	54.7	81.2	209.8
4461	5980	6326.	346.	29.6	70.	99.6	246.4

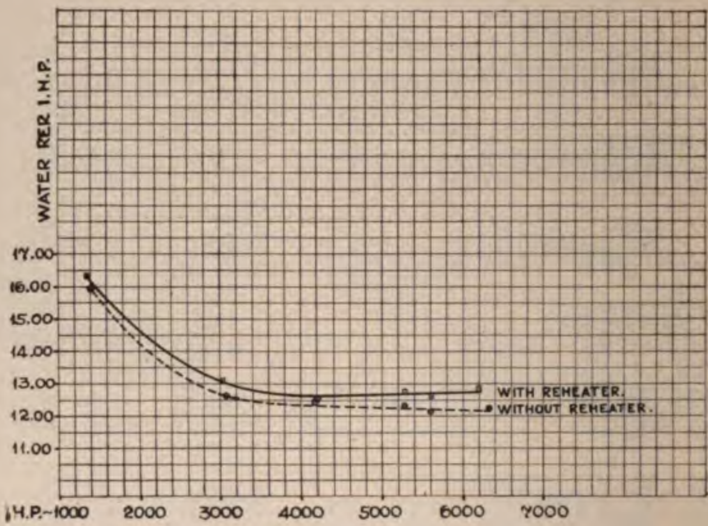
per i.hp-minute and 314 B. T. Us. per kw-minute in column No. 3. Columns Nos. 4 and 5 show the behavior of the engine operating under the same conditions as in columns Nos. 2 and 3, with the exception that the receiver reheater was in use. The steam consumption was 12.81 pounds of water per i.hp-hour and 17.97 pounds of water per kw-hour, the heat consumption 232 B. T. Us. per i.hp-minute, and 325 N. T. Us. per kw-minute in column No. 4. In column No. 5, 12.65 pounds of water per i.hp-hour, 17.81 pounds of water per kw-hour, 229 B. T. Us. per i.hp-minute, 323 B. T. Us. per kw-minute. On comparing both of these with columns No. 2 and No. 3 it will be seen that there is a decided disadvantage in the use of the reheater. To further demonstrate this fact a series of tests with loads varying from

DATA SHEET No. 3

Date and Kind of Test	Feb. 4, 1904, Reheater and Jackets Both Out	Jan. 30, 1904, Reheater and Jackets Both Out	Jan. 30, 1904, Reheater and Jackets Both Out	Jan. 28, 1904, Reheater in Use; Jackets Out	Jan. 28, 1904, Reheater in Use; Jackets Out	Feb. 2, 1904, Reheater and Jackets Both Out	Feb. 2, 1904, Reheater and Jackets Both Out	Jan. 25, 1904, Jackets in Use; Reheater Out	Jan. 25, 1904, Reheater and Jackets Both Used	Feb. 4, 1904, Friction Load; No Reheater or Jackets
Column No.	1	2	3	4	5	6	7	8	9	10
Average kilowatts	3872.	3752.	3751.	3765.	3764.	4483.	867.	.....	.....	.....
" cycles	25.52	25 46	25.60	25.54	25.6	.....	.....	.....	.....	.....
Pressure steam at throttle	185.6	183.1	182.8	184.	184.1	181.6	193.6	187.	184.7	150.7
" at receiver	36.8	23.5	23.3	23.2	23.7	24.8	21.1	23.8	26.2	13.1
" in reheater	0.	0.	0.	138.	138.	0.	0.	0.	130.	0.
" in jackets	0.	0.	0.	0.	0.	0.	0.	29.2	29.7	0.
Vacuum in inches	27.25	26.36	26.36	25 26	25 32	26.60	27.15	24.66	24.44	27.25
Atmospheric, inches	30.26	30.16	30.16	30.44	30.44	30.22	30.22	30.42	30.42	30 27
Temperature high-pressure exhaust	284.8	268.2	268.3	267.6	268.1	277.2	262.7	268.4	271.8	311.3
" low-pressure inlet	284.1	267.5	267.5	277.5	278.2	276.8	262.7	267.8	274.2	289.8
" " exhaust	*125.6	131.	131.5	140.6	140.5	133.7	113.6	143.5	144.7	117.3
Moisture steam at throttle, %	.75	.70	.70	.06	.6	1.11	.78	.7	.7	22.5° Superheat
" " at low-pressure inlet, %	1.29	.....	.....	.....	.....	.....	.....	.....	.....	.....
M. E. P. high-pressure top	52.27	59.57	58.82	.....	.....	75.05	3.64	.....	.....	22.9
" " bottom	62.03	69.89	69 58	.....	.....	80.75	15.42	.....	.....	10.38
" No. 1 low-pressure top	16.87	14.61	14.79	.....	.....	19.66	5.79	.....	.....	.80
" No. 1 " bottom	17.68	15.98	15.47	.....	.....	19.30	5.51	.....	.....	3.46
" No. 2 " top	15.53	14 34	14.21	.....	.....	17.90	5.92	.....	.....	1.22
" No. 2 " bottom	17.43	14.48	14.62	.....	.....	17.48	6.54	.....	.....	1.42
Revolutions per minute for hour	76.30	76.218	76.6	75.383	75.5	74.50	76.75	73.1	73.65	75.
Indicated horse-power high-pressure top	900.	1043.	1035.	.....	.....	1292.	—62.70	.....	.....	395.
" " bot.	1023.	1172.	1172.	.....	.....	1332.	254.4	.....	.....	166.
" " No. 1 low-pres. top.	859.	758.	773.	.....	.....	970.	294.7	.....	.....	40.5
" " No. 1 " bot.	886.	818.	796.	.....	.....	967.	276.1	.....	.....	173.3
" " No. 2 " top.	790.	746.	745.	.....	.....	911.	301.3	.....	.....	62.5
" " No. 2 " bot.	874.	741.	752.	.....	.....	876.	327.7	.....	.....	71.3
Average indicated horse-power per hour	5442.	5278.	5273.	5281.	5315.	6326.	1428.	5294.	5449.	118.6
Water from condenser	61,996	60,686	60,803	62,642	62,398	75,186	22,666	64,614	65,252	16,175
" " receiver	3456.1	3948.	3973.	575.	577.	4422.	189.	2501.	528.	95.
" " reheater	0.	0.	0.	4846.	4470.	0.	0.	0.	3736.	0.
" " jackets	0.	0.	0.	0.	0.	0.	0.	64.	63.	0.
Total water	65,452	64,634	64,776	68,063	67,445	69,603	22,853	67,179	69,579	16,270
Dry steam per hour	64,961	64,182	64,323	67,655	67,041	78,725	22,674	66,709	69,092	16,270
" " " i.hp-hour	11.93	12.158	12.196	12.81	12.61	12.44	15.88	12.59	12.68	1367.
" " " kw-hour	16.78	17.10	17.17	17.97	17.81	17.56	26 13	.....	.....	.....
B. T. Us. " i.hp-minute	221.	223.	224.	232.	229.	229.	295.	228.	229.	.....
" " kw-minute	309.	313.	314.	325.	323.	322.	486.	.....	.....	.....

* Vacuum temperatures are incorrect on account of thermometer being heated by cylinder casting.

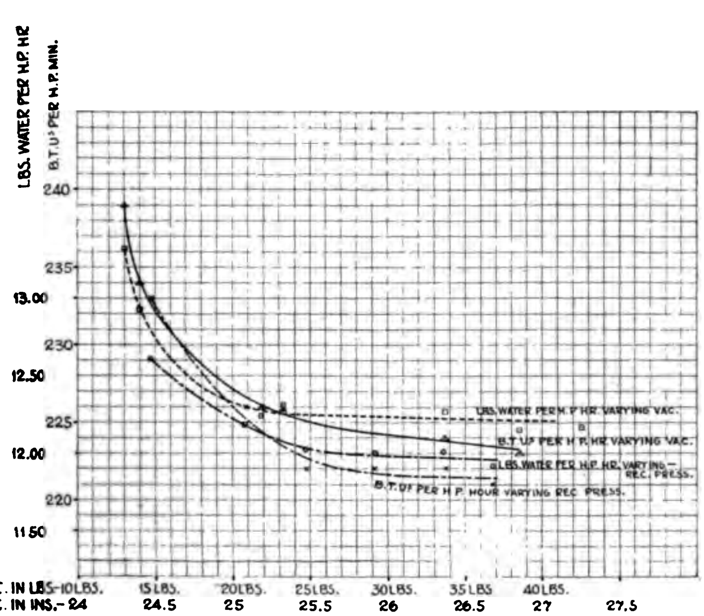
1400 to 6300 horse-power was run, both with and without the reheater; the results are shown graphically by the curves on curve sheet No. 5. Column No. 6 gives the economy for the heaviest load conditions under which the engine was tested, namely, 6326 indicated horse-power. The water consumption was 12.44 pounds per i.hp-hour, 17.56 pounds per kw-hour and the heat consumption 229 B. T. Us. per i.hp-minute and 322 B. T. Us. per kw-minute. Column No. 7 deals with the lightest load conditions under which the engine was tested, or 1428 horse-power, the water consumption in this case being 15.88 pounds per i.hp-hour, 26.13 pounds per kw-hour and the heat



CURVE NO 5

consumption 295 B. T. Us. per i.hp-minute, 486 B. T. Us. per kw-minute. A further reference to curve sheet No. 5 will show the almost absolute uniformity of economy for a considerable range on either side of the normal rating. Column No. 8 shows results of a test made with the low-pressure jackets in use and without the reheater. The water consumption here was 12.59 pounds per i.hp-hour, the heat consumption 228 B. T. Us. per i.hp-minute, showing that the jackets, like the reheater, are a disadvantage on this type of engine. The disadvan-

tage due to jackets, however, was probably increased through leakage into the lower end of the cylinder, which also accounts for the small amount of jacket condensation. Column No. 9 shows the results of a test with both jackets and reheater in use, and, as will be seen, is even worse than column No. 8. Column No. 10 deals with a friction test. In making this test the engine was kept at normal speed and compelled to operate all of the inlet valves by slightly throttling the steam supply; this accounts for the somewhat lower pressures shown, otherwise the conditions



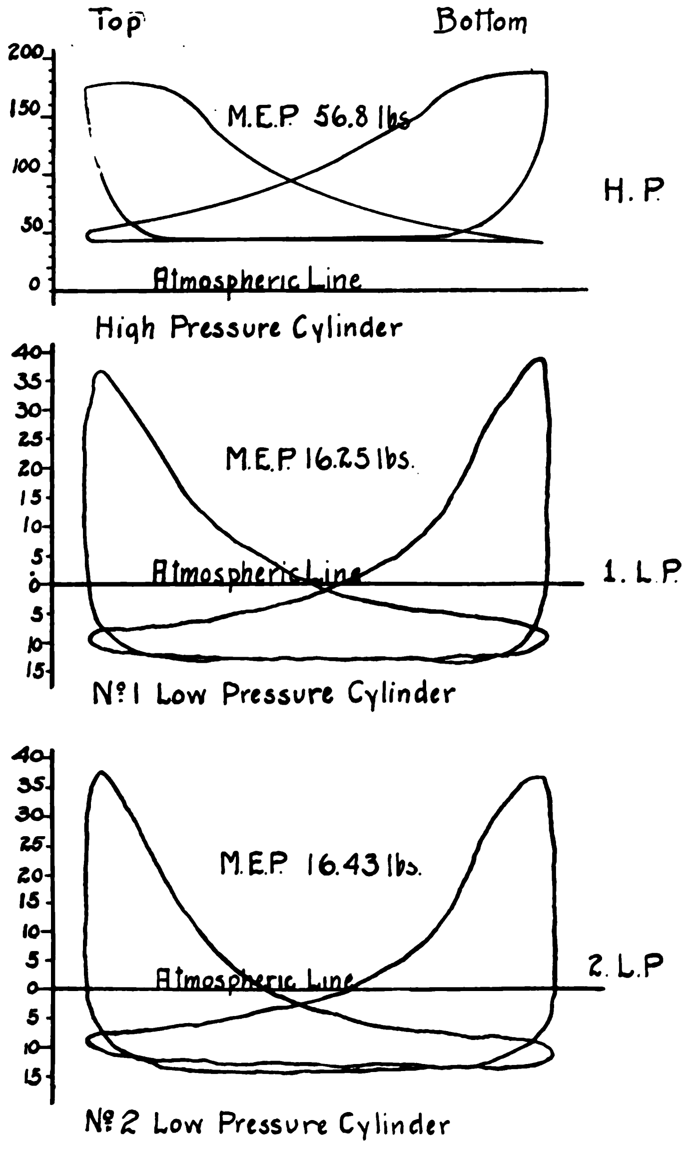
CURVE No. 6

were the same as in actual service. This friction load of 118.6 horse-power or 2.25 per cent of the normal load for the engine appears to be rather low, but as we can see no error in our method of making this test and as the combined engine and generator efficiency adds further proof of its correctness, we know of no reason why it should not be accepted. The increased frictional load due to increased load on the engine can be noted on curve sheet No. 4.

Curve sheet No. 6 is for the purpose of comparing the

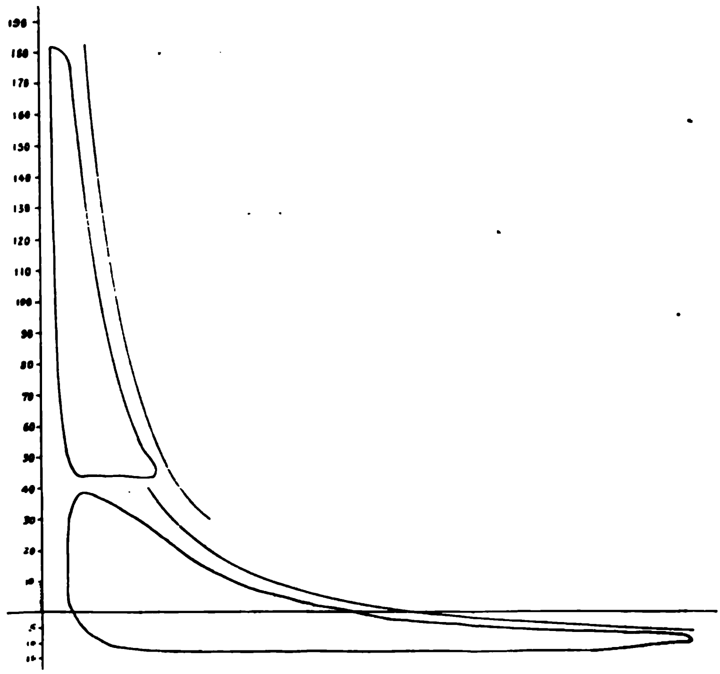
DATA SHEET No. 4

Date	Feb. 4	Feb. 4	Feb. 4	Jan. 30	Feb. 4	Feb. 4	Feb. 2	Jan. 30	Jan. 28	Jan. 25	Jan. 23	Jan. 23
No.	1	2	3	5	9	24	4	8	13	10	22	23
Steam pressure at throttle	185.6	184.2	180.7	185.	180.6	181.3	183.7	182.4	185.1	184.6	182.	180.5
Pressure in receiver	36.8	33.7	29.2	24.8	20.8	14.8	24.7	23.5	19.7	20.9	20.9	28.7
Vacuum in inches	27.2	27.2	27.3	26.3	27.25	27.2	26.75	26.37	25.33	25.19	24.4	24.3
Revolutions per minute	76.3	75.85	76.36	76.8	76.48	75 84	76.55	76.68	76.55	76.2	74 75	74.63
I.hp, high pressure, top	900.	990.	969.	1027.	1088.	1207.	1085.	1013.	......	......	......	......
" " bottom	1023.	1092.	1081.	1174.	1183.	1305.	1161.	1162.	......	......	......	......
" No. 1, low pressure, top	859.	870.	787.	784.	729.	719.	818.	777.	......	......	......	......
" " " bot.	886.	865.	851.	782.	833.	765.	853.	826.	......	......	......	......
" No. 2, " top.	790.	800.	755.	754.	708.	668.	800.	762.	......	......	......	......
" " " bot.	874.	839.	802.	761.	700.	636.	750.	725.	......	......	......	......
Average i.hp per hour	5442.	5526.	5357.	5283.	5360.	5375.	5598.	5265.	5294.	5310.	4930.	5882.
Water per i.hp-hour	11.93	12.02	12.01	12.08	12.19	12.6	12 11	12.19	12.39	12.24	12.93	13.24
B. T. Us. per i.hp-minute	221.	222.	222.	222.	226.	233.	223.	224.	226.	226.	234.	239.


Top
Bottom
200
150
100
50
0
M.E.P 56.8 lbs
Atmospheric Line
H.P
High Pressure Cylinder
40
35
30
25
20
15
10
5
0
5
10
15
M.E.P 16.25 lbs.
Atmospheric Line
1. L.P
No. 1 Low Pressure Cylinder
40
35
30
25
20
15
10
5
0
5
10
15
M.E.P 16.43 lbs.
Atmospheric Line
2. L.P
No. 2 Low Pressure Cylinder

CURVE NO. 7

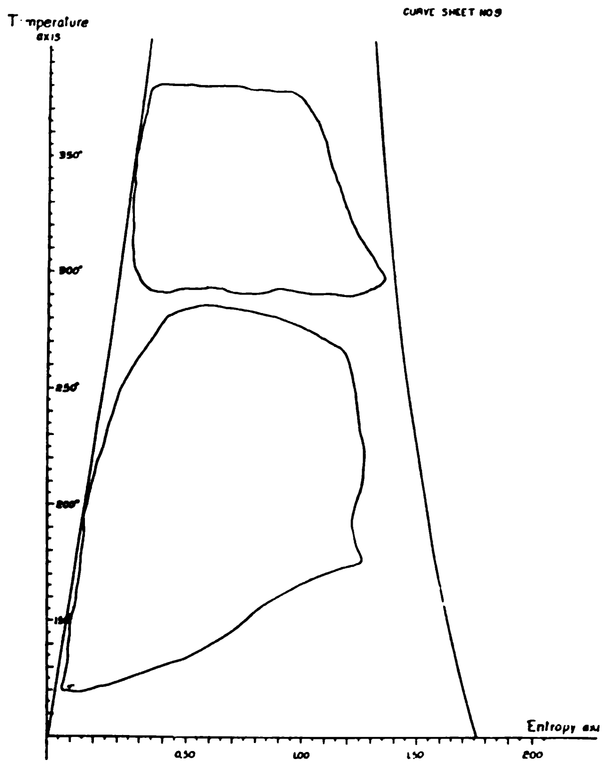
effect of varying vacuum and varying receiver pressure or distribution of load upon economy both in water consumption and heat consumption. The data from which these curves are derived will be found on data sheet No. 4. An examination of the curves will show that increasing the vacuum from 25.3 inches to 27.3 inches decreased the water consumption only .06



CURVE No. 8

pound and the heat consumption 2.6 B. T. U's., whereas increasing the receiver pressure from 21 pounds to 36.8 pounds or changing the distribution of load from about two-fifths on the high-pressure cylinder and three-fifths on the two low-pressure cylinders to about equal load on all three cylinders, decreases the water consumption .25 pound and the heat consumption 2.6

B. T. U's. The heat consumption estimates are based on the assumption that all water is returned to the boilers at the temperature of the steam from which it is condensed. Curve sheet No. 7 shows the reproduction of a set of indicator diagrams taken during the test of February 4th, as described in column No. 1 on data sheet No. 3. Curve sheet No. 8 shows these dia-



CURVE No. 9

grams combined. Curve sheet No. 9 shows the temperature entropy diagram, and data sheet No. 5 gives further engine data and the entropy account. The authors desire to acknowledge their indebtedness to Mr. G. A. Orrok in the working out of the entropy diagram.

DATA SHEET No. 5

ENGINE No. 8, WATERSIDE STATION, NEW YORK ELECTRIC COMPANY
Date of Test, February 4, 1904

Condition of Steam, 99.25% Dry
Feed Water per i.hp per hour, 11.93
Revolutions per minute, 76.3; per pound Feed Water, .07

	High Pressure	Low Pressure	Totals
CYLINDERS			
Diameter	43.98 in.	75.65 in.	......
Stroke	60.00 "	60.00 "	......
Percentage of clearance, average	10.425	4.225	......
Mean effective pressure	56.8 lbs.	16.34 lbs.	......
Indicated horse-power	2085.	3370.	5455.
Piston displacement per lb. of feed	7.4 cu. ft.	4.72 cu. ft.	......
Cushion steam per lb. of feed by weight	.313 lbs.	.067 lbs.	......
ENTROPY ACCOUNT			
Work theoretically available per lb. of feed	......	......	256,000 ft.lbs.
Work actually developed per lb. of feed, by indicator	......	......	165,700 "
Work actually developed per lb. of feed, entropy diagram	60,000 ft.lbs.	114,500 ft.lbs.	174,500 "
Loss from wire drawing	310 "	3,000 "	3,310 "
" " initial condensation	25,700 "	30,400 "	56,100 "
" " condensation during expansion	......	220 "	220 "
Gain from re-evaporation during expansion	—13,600 "	—8,690 "	—22,290 "
Loss from incomplete expansion	220 "	29,100 "	29,320 "
" " clearance	2,110 "	8,240 "	10,350 "
" " back pressure	270 "	450 "	720 "
Receiver losses	......	......	3,270 "
Algebraic sum of losses and gains	......	......	255,500 ft.lbs.

THE PRESIDENT: Gentlemen, with your permission I am going to change the order of programme just a trifle and pass the paper on mechanical stokers for the next half hour, and take up the report of the committee on investigation of the steam turbine, Mr. W. C. L. Eglin, of Philadelphia, being the chairman of the committee.

Mr. Eglin presented the report of the committee.

REPORT OF THE COMMITTEE FOR THE INVESTIGATION OF THE STEAM TURBINE

Mr. President and Gentlemen of the National Electric Light Association:

Your committee during the past year has endeavored to collect data covering the various details concerning steam turbines. It has also communicated with the users of steam turbines and investigated the work of the various manufacturers of commercial turbines. The rapid development of the steam turbine and the demand upon the manufacturers have been so great as to interfere with obtaining results on the various sizes and makes of turbines.

The committee has divided the report into various sections, starting with a brief history of the art, the makers' descriptions of the various machines, the manufacturing plants, efficiency tests, and the opinions of users; finally, the general conclusions drawn from its investigations, which are submitted for your consideration.

HISTORY

The steam turbine, like many other inventions, dates back before the Christian era, starting with the Hero engine. Most of the important physicists of this age in thermodynamics have devoted some time and attention to this subject. James Watt, so commonly reputed the inventor of the steam engine, also invented a rotary engine of the turbine type.

A turbine is a machine in which rotary motion is obtained by the gradual change of momentum of a fluid. The velocity of steam when expanded from the usual pressures used by reciprocating engines is so very great that most of the investigators of the subject of steam turbines concluded that an efficient machine could not be built except when operated at a speed that, in their judgment, was prohibitive.

Water turbines have been used extensively for many years,

these machines having a high efficiency and giving satisfactory commercial results. The problem of designing a water turbine is very much simplified, as the velocity of the water, even at the greatest heads that have been used, is very much less than the velocity of steam when expanded from 125 pounds to atmospheric pressure.

About twenty years ago the Hon. Charles Algernon Parsons, of England, and Carl De Laval, of Sweden, devoted their attention to the investigation of steam turbines, and each of them has developed successful designs. The early work of these investigators was confined to small-sized machines, for two reasons: First, they were unable to find means of utilizing power from this machine when operating at high speeds, as at that time the design of the generator had not progressed so far that such generators could be built; and second, there was little commercial use to which the larger size of turbines could be put.

The first De Laval machine was utilized for the well-known De Laval cream separator, and Parsons' early turbines were used to drive small dynamos. Parsons also experimented largely with turbines for marine purposes, designing a special propeller suitable for the high speeds of the turbine. Through the efforts of Parsons and De Laval and the very excellent pioneer work done by them, the attention of the engineering world has been forced to the new aspirants for first honors in the field of prime movers. In the United States Mr. C. G. Curtis, of New York, began experimental investigation on the subject of steam turbines about ten years ago. He later associated himself with the General Electric Company, and with the very large facilities at the command of the engineers of this company a great deal of important new work has been done. To Mr. C. G. Curtis and Mr. W. L. R. Emmet is due the credit for most of the advance work that has been made on the turbine in the United States.

The high speed of the turbine shaft did not adapt itself to the general classes of work, so its field was comparatively limited as a prime mover, and the difficulties of gearing down to operate relatively slow-moving machines, which it was intended to drive, made it cumbersome and expensive. With the introduction of individual drives of machines and tools

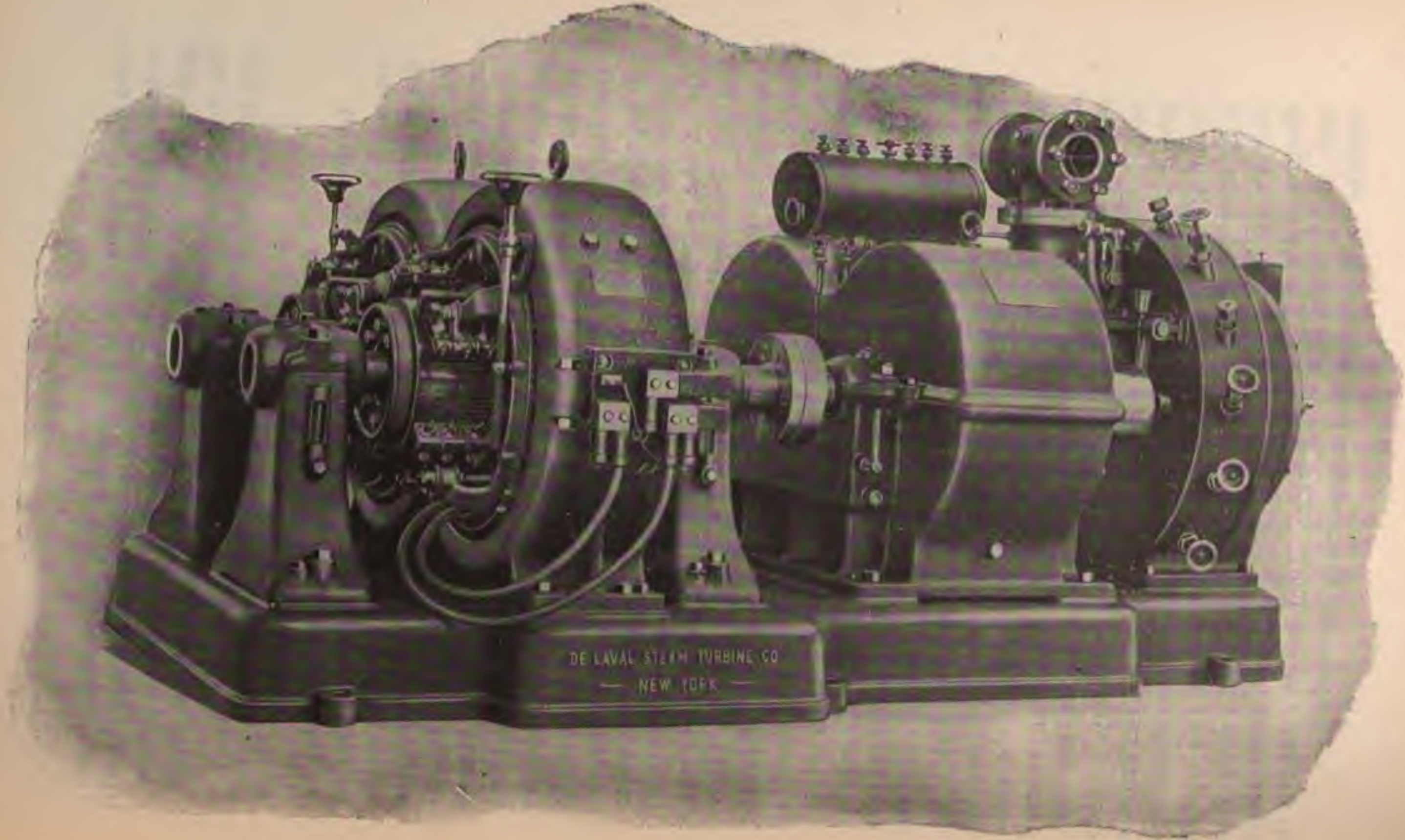


Fig. 1—De Laval Steam Turbine Dynamo

from electric generators and motors the field of the turbine was widened practically to that of first importance. De Laval geared down his turbine wheel in the ratio of 10 to 1, so that the driven shaft was within the limits of speed of the standard commercial generators.

DE LAVAL TURBINE

In the De Laval type of turbine the steam is expanded by means of a nozzle so as to obtain the maximum velocity that the pressure is capable of transmitting to the steam, utilizing this velocity by impinging the steam against buckets arranged on the periphery of a wheel. The steam may be subdivided and expanded through a number of nozzles arranged at various points on the periphery of the wheel. On account of the enormously high velocity of the steam, it is necessary that this wheel should revolve at a high speed; the more nearly it approaches the velocity of the steam, the greater the efficiency, the economical speed of buckets being half the velocity of the steam. These high velocities present three difficulties: first, mechanical difficulty of building a wheel to withstand stresses set up by this high velocity; second, the balancing of the wheel so as to rotate in bearings without vibration; third, arranging the machine so that the speed of the shaft can be reduced in order to adapt itself to the operation of the commercial generators.

De Laval has carefully worked out the proportion of this wheel so as to withstand the stresses, and has overcome the difficulty due to vibration by means of a flexible steel shaft. The case of the turbine wheel is made of cast steel, and the wheel is recessed near the rim so that in the event of the wheel exceeding the speed limit by 100 per cent it will break in small sections and the broken parts will be kept within the case, and therefore will not damage surrounding property. Safety devices are also attached to the governor, to prevent the machine "running away." The flexibility of the shaft necessitates that it be small in diameter, thus limiting the size of this type of turbine. These turbines are being very successfully built from designs of the European De Laval Company with some important modifications to suit American demands. We believe the machine to be efficient and commercially successful.

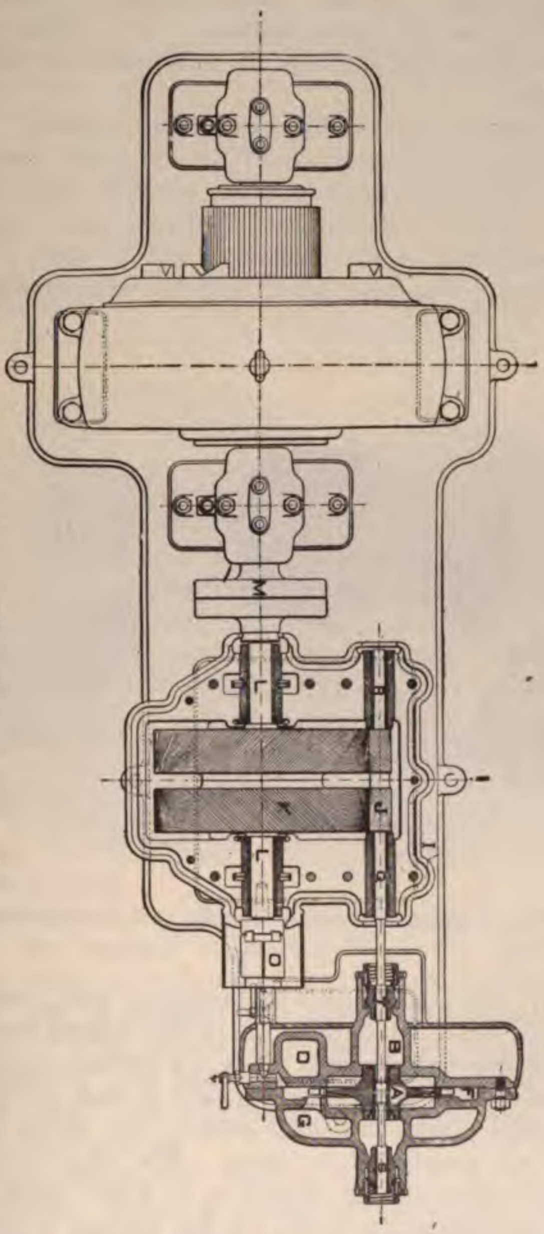


FIG. 2—SECTIONAL PLAN, DE LAVAL TURBINE, 30 HORSE-POWER

This company has paid special attention to turbine pumps driven direct by the steam turbines. Curves from tests made by Denton and Kent, showing the performance of these pumps, are attached.

The manufacturer's description is as follows:

The general construction of the De Laval steam turbine will be clearly understood from the sectional plan (Figure 2), and the half-tone showing the different parts (Figure 3). The construction of the turbine, it will be seen, presents no extraordinary departure from everyday engineering practice.

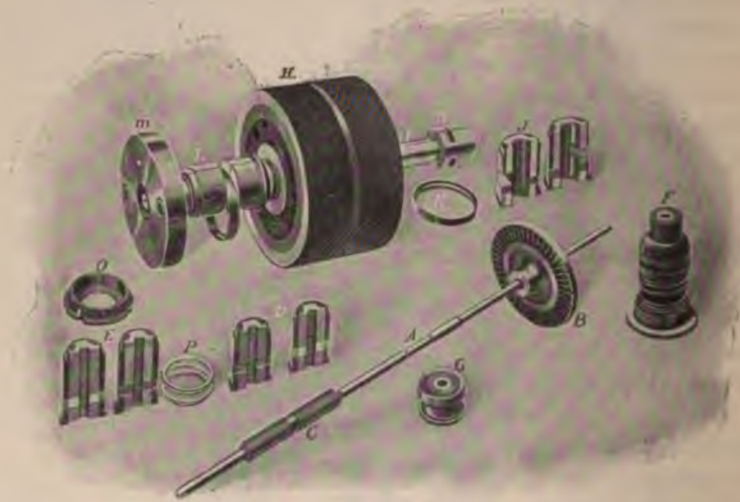


FIG. 3—WORKING PARTS OF THE DE LAVAL STEAM TURBINE

However, the workmanship and material used, owing to the high speed employed, must be of the very highest quality.

Referring to Figure 3, *B* is the turbine wheel mounted upon the slender flexible shaft *A*, and in such position relative to the wheel case as to revolve entirely free, liberal space being allowed on each side, as shown. The wheel case and the wheel-case cover are so shaped as to form "safety bearings" around the hub of the wheel, for the purpose of catching and checking its speed in case of an accident to the shaft.

The steam after passing through the governor valve enters the steam chamber, where it is distributed to the various nozzles. These, according to the size of machine, range in number from 1 to 15. They are generally fitted with shutting-off valves *E* (Figure 4), by which one or more nozzles can be cut out when the turbine is not loaded to its full capacity. This allows steam of boiler pressure to be almost always used, and adds to the economy on light loads.

After passing through the nozzles, the steam, as elsewhere explained, is now completely expanded, and in blowing through the buckets *F* (Figure 4), its kinetic energy is transferred to the turbine wheel. After performing its work the

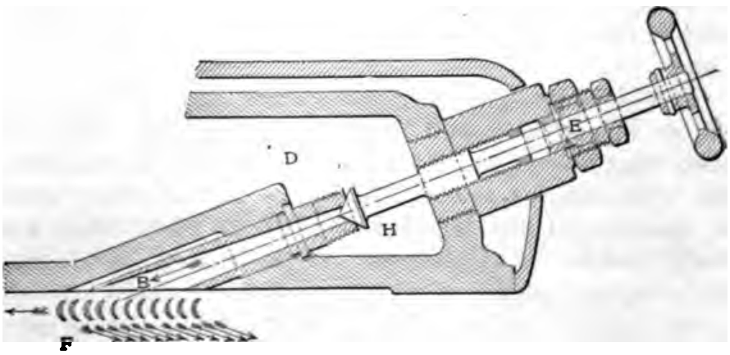


FIG. 4—DE LAVAL NOZZLE

steam passes into the chamber *G* (Figure 2), and out through the exhaust opening.

The velocity of the turbine wheel and shaft, in most cases too great for practical utilization direct, is considerably reduced by means of a pair of spiral gears, usually made 10 to 1. The gear is mounted and inclosed in the gear case *I* (Figure 2). *J* is the pinion made solid with the flexible shaft and engaging the gear wheel *K*. This latter is forced upon the shaft *L*, which with couplings, *M*, connects to the dynamo or is extended for pulley.

Bearings—The flexible shaft is supported in three bearings (Figure 2). *Q* and *R* are the pinion bearings and *S* is the main shaft bearing which carries the greater part of the

weight of the wheel. This latter bearing is self-aligning and is held to its seat by the spring and cap shown. *T* is the flexible bearing. This bearing is entirely free to oscillate with the shaft, and its only purpose is to prevent escape of steam when running non-condensing, or air from entering the wheel case when the turbine is running condensing. All the bearings of the flexible shaft, as well as the gear wheel, are lubricated from a central oil reservoir, mounted upon the gear case; all other bearings are self-oiling. The bearings are plain and simple in construction, and made in two halves, so as to be taken out easily and examined. They are lined with the best quality of anti-friction metal, are reamed true, round, and to exact size, and have the outside surface ground to insure pertect fitting and alignment. The bearings even in the largest sizes are removed and replaced without raising the shaft from its seat.

Gear Wheels—The gear wheels are made of solid cast steel, or of cast iron with steel rims pressed on. The teeth in two rows are set at an angle of 90 degrees to each other. This, while insuring smooth running, at the same time checks any tendency of the wheel and shaft to move lengthwise, thereby making a troublesome thrust bearing unnecessary. The gears are cut on automatic machines designed specially for this purpose, and a degree of accuracy has been attained not heretofore approached in gear-wheel production. Owing to the high speed of the gears and their perfect alignment, the stress on the teeth is extremely small, and gears that have been examined after continuous operation for seven or eight years show no appreciable wear.

Flexible Shafts—The flexible shaft is mainly supported on each side of the pinion by main bearings *Q* and *R*; the shaft is at the same time made very slender, which gives it a certain amount of flexibility and allows the turbine wheel, when the so-called critical speed is reached, to revolve around its true centre of gravity. This critical speed, dependent upon the flexibility of the shaft, occurs well below the normal speed of the turbine and marks the disappearance of all virbrations.

Turbine Wheel—The turbine wheel is by far the most important part of the De Laval steam turbine and is in its present form the result of numerous experiments both as to

shape and material. It is made of forged nickel-steel, and will withstand more than double the normal speed before showing any signs of distress. In the smaller sizes the turbine wheels have a hole through the centre and are forced upon a taper sleeve shrunk on to the shaft. The larger wheels are made solid, with the shaft in two pieces screwed to the flanges of the wheel. The buckets are drop-forged and made

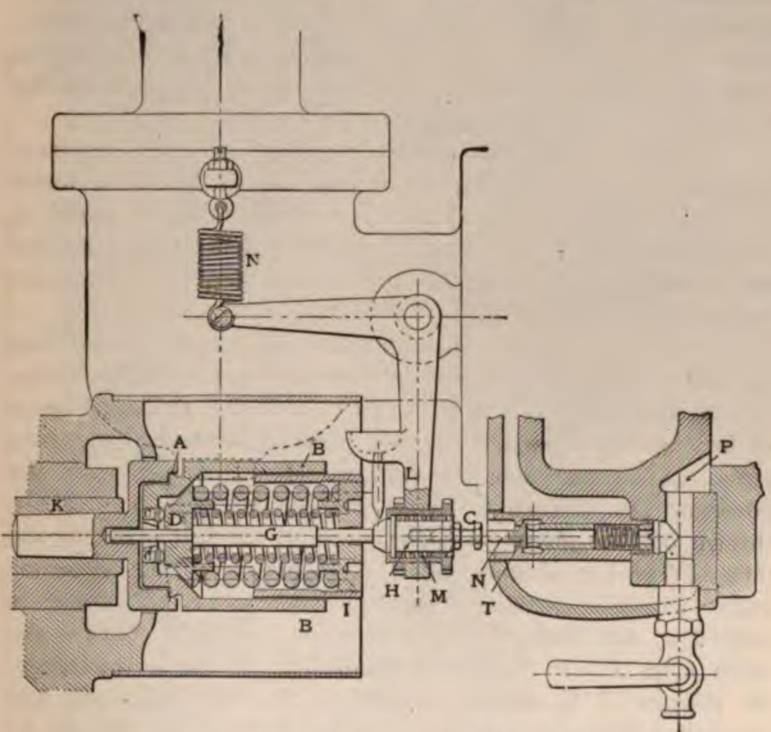


FIG. 5—DE LAVAL GOVERNOR AND VACUUM VALVE

with bulb shank fitted in slots milled in the rim of the wheel. By this method the buckets can easily be taken out and new ones inserted, should occasion require, without damage to the wheel.

Governor—With the high speed employed in the De Laval steam turbine a governor of small dimensions, and yet very effective, can be used. The governor, shown in detail (Figure

5), is compact and simple in construction. The two weights, *B*, are pivoted on knife edges *A*, with hardened pins *C* bearing on the spring seat *D*. *E* is the governor body, fitted in the end of the gear-wheel shaft *K*, and has seats milled for the knife edges *A*. It is afterwards reduced in diameter to pass inside of the weights, and is in its outer end threaded for the adjusting nut *I*, by means of which the spring and eventually the speed of the turbine is adjusted. When the speed exceeds the normal, the weights, affected by the centrifugal force, spread apart and, pressing on the spring seat *D*, push the governor pin *G* forward, cutting off part of the flow of steam.

Vacuum Valve—The vacuum valve is only necessary when running condensing, as in this case it has been found that the governor valve alone is unable to hold the speed of the turbine within the desirable narrow limit during sudden and great changes in the load. The function of the vacuum valve is as follows:

The governor pin *G* actuates the plunger *H* screwed into the bell crank *L*, however, without moving the plunger relative to said crank. This is on account of the spring *M* being stiffer than the spring *N*, whose purpose is to keep the governor valve open and the plunger *H* in contact with the governor pin. When a large part of the load is suddenly thrown off, the governor opens, pushing the bell crank in the direction of the vacuum valve *T*. This closes the governor valve, which is completely shut off when the bell crank is pushed so far forward that the screw *O* barely touches the valve stem *J*. If this is not sufficient to check the speed, the plunger *H* is pushed forward in the now stationary bell crank and opens the vacuum valve. This allows the air to rush into the space *P*, where the turbine wheel revolves, effectually checking its speed.

PARSONS TURBINE

Parsons' design differs radically from the De Laval in that the steam is expanded gradually through the machine. A series of buckets is attached to the shaft. These buckets are free to move with the shaft and between each set is placed a set of fixed buckets attached to the shell of the turbine.

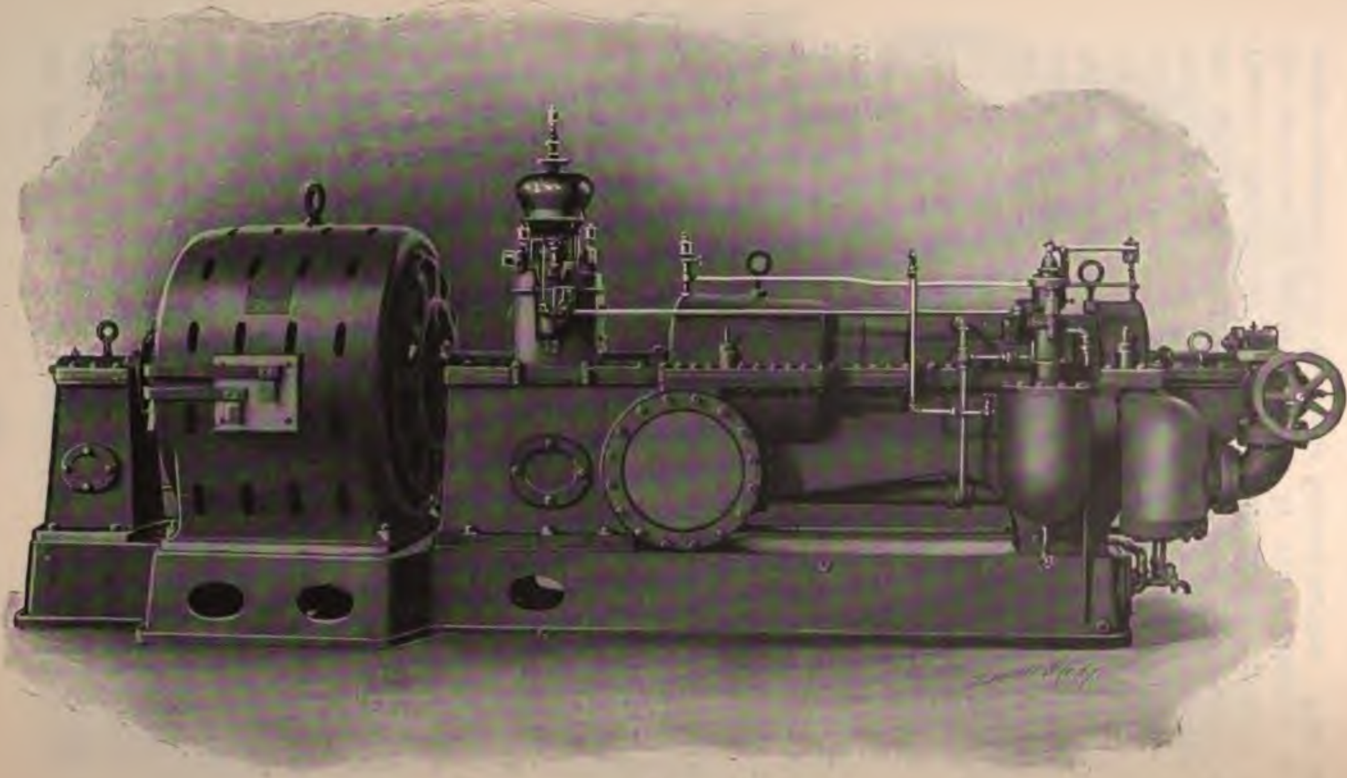


Fig. 6—400-Kw Westinghouse-Parsons Turbine Generator Unit

The fixed buckets act as guides to direct the steam at the proper angle against the next set of buckets. Steam is admitted at one end and travels parallel with the shaft, the length of the buckets increasing as the steam progresses, in order to provide for the increased volume of steam due to the expansion, exhausting at the opposite end from the admission. This type of turbine is known as the parallel-flow turbine.

Parsons and others have also experimented with types of turbines known as the radial flow, in which the steam is admitted near the centre of the shaft, passing through a series of buckets arranged radially. This radial-form turbine entails so many mechanical difficulties in its construction that it has never been developed by Parsons and others to commercial success.

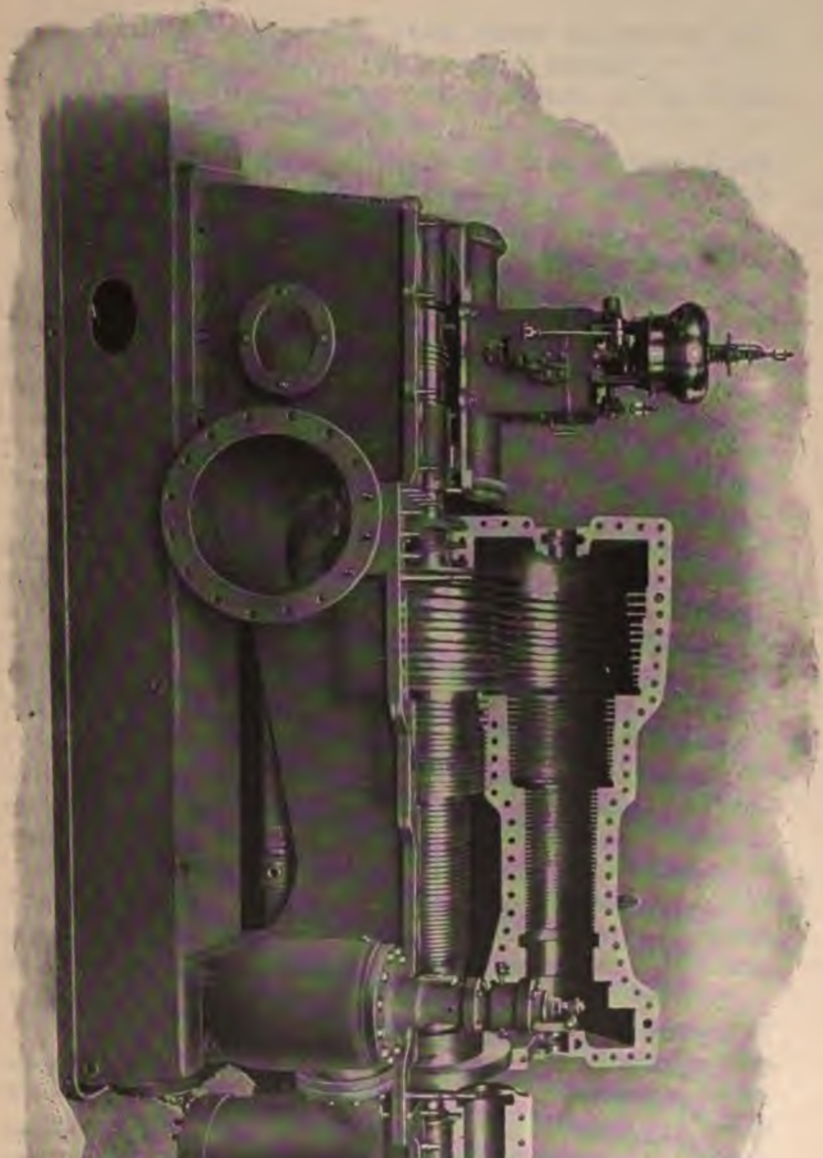
The end thrust of the buckets in the parallel-flow type of turbine is counter-balanced by a series of pistons.

The steam leakage around the shafts, where it passes through the casing, is prevented by arrangement of water packing. On small sizes the vibration of the shaft is taken up by means of a flexible bearing, which consists of three sleeves loosely fitting one within the other. A small thrust bearing is also used to overcome any inaccuracies in the balancing, as well as for determining the position of the shaft so that the blades have an equal clearance in their relation to the fixed buckets.

The manufacturer's description is as follows:

THE WESTINGHOUSE-PARSONS TURBINE

All turbines operate upon the broad principle of the kinetic energy of velocity of moving steam abstracted by the vanes of a rotating bucket wheel placed in the path of the jets. The Parsons construction, however, differs from the various other types using steam as a simple impulse water-wheel, in that it combines the action of an impulse turbine with that of a reaction turbine, thus bearing a much closer resemblance to the ordinary hydraulic reaction turbine; furthermore, the Parsons type employs the principle of multiple expansion for the reduction of steam velocities in contradistinction to a single expansion, as in the simple impulse turbine. This may



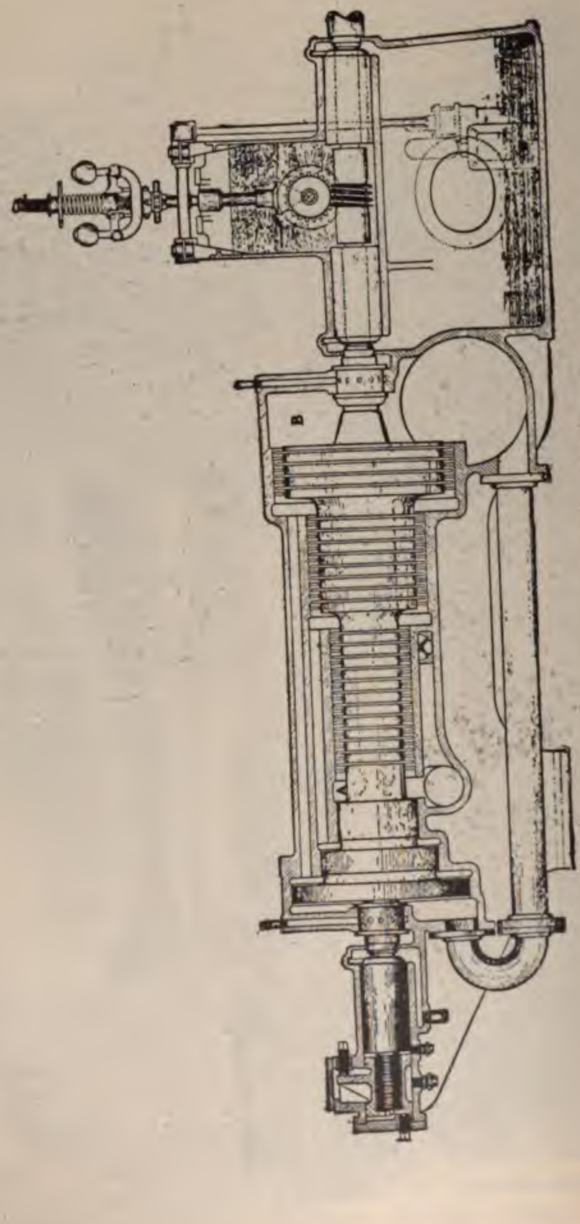


Fig. 8—Section of Westinghouse-Parsons Turbine

be perceived from Figure 8, which shows the general construction of a Westinghouse-Parsons steam turbine.

Three essential elements may be observed: (1) the rotor, (2) the stator, and (3) the balancing pistons.

The rotor consists of a cylinder of three or more drums of increasing diameter, upon the periphery of each of which are mounted numerous rings of radial vanes.

The stator comprises a split casing of interior proportions conforming to those of the rotating cylinder. The interior walls of the casing are studded with rows of stationary radial blades corresponding to those on the moving cylinder but assembled with a reverse pitch.

High-pressure steam enters the turbine through the annular orifice *A*, expanding to the right through the several stages to the exhaust *B*. The rotating balance pistons are equal in number to the number of drums, and each piston is of such diameter that the axial thrust resulting from the impact of the steam upon the blades of any drum is exactly balanced by corresponding pressure against the pistons. These pressures are at all times equalized by means of the ports and the pipes, so that the balancing of the rotating element is entirely independent of the absolute or relative pressures in the various stages. The adjustment bearing is therefore entirely relieved of axial thrusts. Its only function is to preserve the proper mechanical clearances between moving and stationary parts.

The balance pistons revolve within the casing with a close fit but without mechanical friction. Leakage of steam past the piston is prevented by deep grooves in the periphery which interpose so devious a path for the steam as to render loss from this source quite inappreciable.

In this form of turbine the area for the expansion of steam is secured by gradually increasing the annular volume between rotor and stator, which may be regarded as single annular nozzles. Starting from *A*, blades of increasing length are employed in the first drum until a mechanical limit is reached, when the diameter is abruptly increased and a second progression begun with shorter blades, these again lengthening to the end of the second drum.

Blades—The form of the blade used is the result of both

theory and extensive experiment. They are usually made of a special bronze, cold drawn, of tensile strength averaging 75,000 to 80,000 pounds per square inch, with 20 to 30 per cent elongation. This material is drawn out into long strips and the blades are then sawed off to the proper lengths. They are assembled by a calking process in grooves turned in the steam surfaces of rotor and stator. This method has proven so effective that the force required to pull out the blades exceeds the elastic limit of the material. It also greatly facilitates repairs, should such ever prove necessary. In comparison with the ultimate strength of the blades, the pressure exerted upon them from the impact of steam is minute, varying from .055 to .065 pound in a 400-kw turbine, which is obviously but a small percentage of their bending strength. The very multiplicity of blades employed in this type therefore results in great inherent strength of construction.

Clearances—Running clearances, both axial and radial, are ample to insure freedom of motion in all directions. Flexure or sagging of the shaft at the centre is prevented by rigid quill construction, and the danger from adjacent rows of blades coming in contact is practically impossible, on account of the large clearances employed, which vary from .125 inch to .75 inch, according to the size of the blades. These clearances are maintained by the adjustment blocks.

Expansion—In the turbine approximately adiabatic expansion is realized, as no heat is taken in or given out, and the temperature of the casing remains approximately equal to that of the steam in each expansion stage. Both parts of the turbine are therefore approximately at the same temperature as that of the steam passing through the machine, and both expand and contract as a unit, thus preserving the original relation between moving and stationary blades. The stator, or casing, is anchored to the bed plate at the exhaust end by heavy bolts, while the steam end rests upon a foot sliding between machine ways. The entire body of metal is thus free to move according to the temperature of the steam used.

Inspection—In order to facilitate inspection of the interior, the casing is split along a horizontal plane passing through the centre of the shaft, and the upper half may be then lifted out by a crane, vertical guide rods preventing injury to the

blades during this operation, as well as insuring the accurate registering of parts when again assembled. Each drum of the casing is designed to withstand a considerably greater pressure than would occur in practice, and is tested under this pressure at the shops, to eliminate defects. A relief valve at the top of the exhaust *B* prevents rupture of the casing in case of excessive back pressure.

Bearings—Oil-cushioned bearings are employed on all turbines running at speeds above 1200 r.p.m., in order to provide sufficient flexibility to absorb vibrations occurring while the turbine is passing its critical speed; that is, changing from its geometric to its gravity axis. This construction consists of a nest of loosely fitting metallic sleeves surrounding the shaft and resting in a self-aligning seat in the pedestal. Oil circulates between the sleeves, and, by capillary action, fluid cushions are formed which restrain vibration and at the same time give the desired flexibility. The shaft is therefore built as rigidly as is necessary to prevent flexure within the prescribed limits.

In turbines above 1000-kw capacity, the speeds are so low as not to necessitate the flexible bearing, so that a solid self-aligning bearing is used, split horizontally and adjusted by shims. The bearing surfaces are sufficient to carry the weight of the rotor on oil films without the use of forced lubrication. They are supplied by a small plunger pump driven by the turbine, which circulates oil through a closed system, comprising, in the order of their arrangement, pump, oil cooler, bearings, and reservoir. The pressure of oil at the bearings never exceeds an equivalent static head of one to three feet.

The adjustment bearing resembles a marine-engine thrust bearing. It is built in two parts, set up in opposite directions by the levers and set screws shown. By means of graduations on the heads of the lower set screws, the axial clearances in the turbine may be determined within hundredths of an inch, and kept permanent.

Air-tight and steam-tight packing glands close the shaft openings in the casing, so as to prevent the leakage of air into the exhaust and thereby impairing the vacuum. These glands are sealed by minute streams of pure water, which finally escape to the condenser.

No oil of any nature is used in the interior of the turbine.

Valves—Two steam-admission valves are employed; a primary or main valve and a secondary valve. Both are of the balanced, double-beat poppet type, and are removable, together with their bonnets, through openings in the steam chest. The primary valve is in operation on all loads, but the secondary valve opens only when a predetermined degree of overload is reached. It then permits the entrance of steam to the second drum of the turbine in proportion to the overload, thus increasing the internal pressure and consequently the power. Each

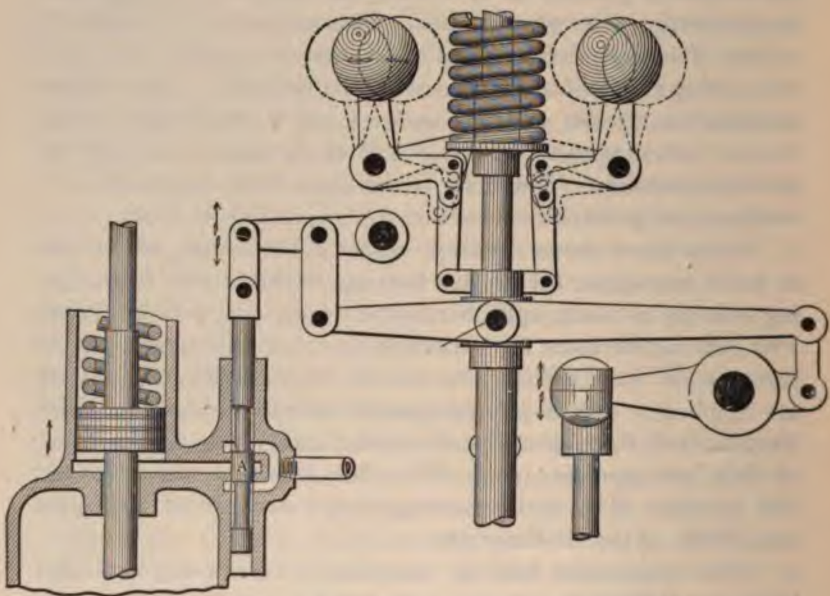


FIG. 9—GOVERNOR FOR WESTINGHOUSE-PARSONS TURBINE

valve is operated by a small steam piston controlled by a relay valve, which in turn receives reciprocating motion from an eccentric driven from the worm shown at the end of shaft, which also drives the governor. High-pressure steam is thus admitted to the turbine in short puffs with a constant frequency of about 150 strokes per minute.

Governor—The function of the governor is to vary the amplitude of this reciprocating motion as transmitted to the

valve, thus in turn varying the period of steam admission to the turbine in proportion to the load. At full loads, the puffs of steam merge into nearly continuous blast, while at light loads, the steam is admitted only during brief periods. The ultimate objects of this method of governing are: (1) to utilize high-pressure steam as far as possible at all loads; (2) to impress upon the governor mechanism a slight oscillatory motion sufficient to prevent the sticking of parts due to friction, thus improving the regulations.

The governor is of the centrifugal type with bell crank ball levers swung on knife edges, and resisted by a spiral spring, the pressure of which is adjusted by a knurled tension nut. This governor spring is mounted between ball bearings so that it may be brought to rest while the turbine is running. By increasing the spring tension, the speed of the turbine is increased, and *vice versa.* This affords a simple and effective means of synchronizing an alternating-current generator for parallel operation, and for subsequently distributing the load between two or more alternating-current generators operating in parallel.

Speeds—Precautionary measures have been adopted in order to prevent the attainment by the turbines of excessive or destructive speeds. In machines of all sizes, the pilot valve controlling the main admission valve is so designed that an abnormal oscillation in either direction from mid-position will result in permanently closing the admission valve so that the turbine will come to rest, as in the case of a serious and prolonged short-circuit, or the breaking of the governor mechanism. In addition, a safety stop is frequently employed, especially in large sizes, which operates quite independently of the governor mechanism. It is usually mounted at the end of the turbine shaft and consists of a centrifugal governor that releases a trip valve at any predetermined speed. This valve in turn operates, through high-pressure steam, an auxiliary quick-closing throttle valve located in the main steam pipe. This safety stop may also be conveniently used in shutting down the turbine in emergencies, it being only necessary to trip the valve by hand.

The Parsons turbine has been developed in this country by the Westinghouse Machine Company, of Pittsburg, who have introduced a number of improvements in its construction. These

cated by the thermometer at the point of inlet, being gradually reduced until at the point of outlet the hand may be placed on the shell without being affected.

Special generators were designed to suit the turbine.

The manufacturer's description is as follows:

The principle of the Curtis turbine differs from that of any

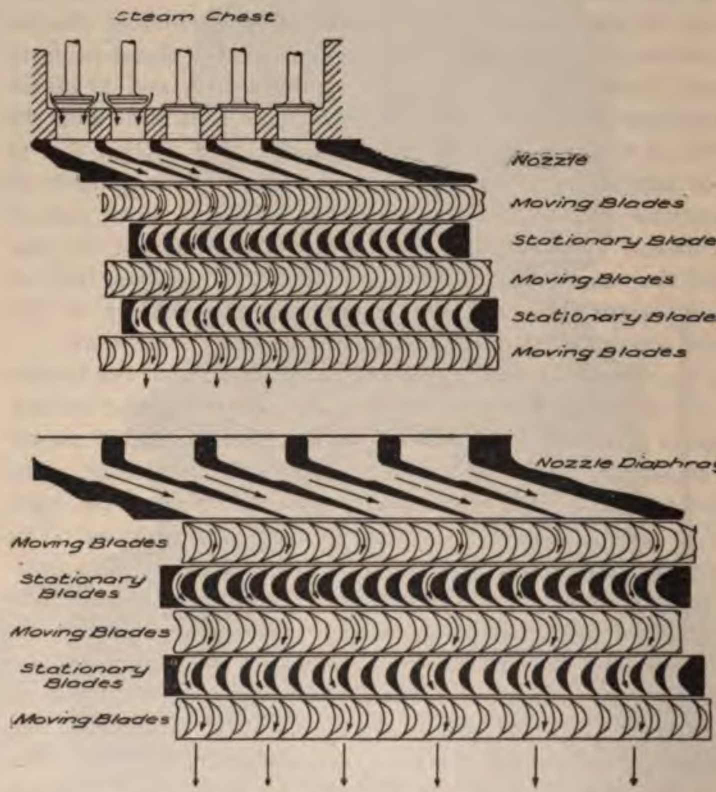


FIG. 11—DIAGRAM OF NOZZLES AND BUCKETS IN CURTIS STEAM TURBINE

other type in that it permits the use of moderate rotative speeds and very compact and simple mechanism. The turbine is divided into stages, each of which may contain one, two, or more, revolving buckets supplied with steam from a set of expansion nozzles. The work is divided among several stages, consequently the nozzle velocity in each stage is reduced, thereby rendering

Nozzle for Curtis Steam Turbine

Revolving Buckets for Curtis Steam Turbine

Stationary Buckets for Curtis Steam Turbine

Fig. 12

the nozzle action more efficient and perfect than it can be where a higher initial velocity is imparted. Under this arrangement the energy of the moving steam is effectively given up to the revolving part. The division of pressure between the stages is so arranged as to utilize the largest possible proportion of the energy of expansion. The position of the moving and stationary buckets with relation to the nozzle is shown in the diagram.

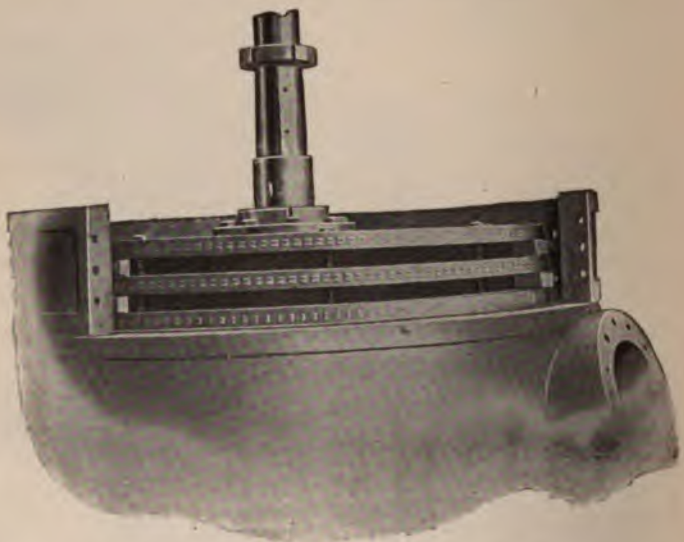


FIG. 13—SECTION SHOWING THE ARRANGEMENT OF REVOLVING AND STATIONARY BUCKETS IN A STAGE OF CURTIS TURBINE

VERTICAL TYPE

For turbines of large capacity the General Electric Company has applied these principles to the development of a turbine with a vertical shaft. All imposition of weight on cylindrical bearings and tendency to shaft reflection are avoided, as well as all difficulties due to irregularity of expansion or imperfection of support. The result is a turbine of the most compact form and of the greatest mechanical simplicity.

Step Bearing—The step bearing at the end of the vertical shaft supports the weight of the revolving part and maintains the revolving and stationary elements in exact relation. It con-

sists of two cylindrical cast-iron plates bearing upon each other and with a central recess to receive the lubricating fluid, which is forced in by steam or electrically-driven pumps with a pressure sufficient to sustain the weight of the revolving part. It is apparent that the entire weight of the machine is thus carried on a film of lubricating fluid and that there is no appreciable friction. When the flow of liquid is interrupted the bearing is slowly worn away, but experience has shown that interruptions in the flow seldom cause any deterioration that prevents the continuance of the machine in service after the flow is reestablished. The tendency of the bearing in such cases is to wear itself to a new surface so that it operates normally.

Clearances—In consequence of the exact relation maintained between the revolving and stationary elements by the step bearing, it is possible to operate the turbines with very small clearances between the moving and stationary buckets. Experience, however, has shown that the reduction of clearance beyond a certain point is not beneficial, and that clearances less than those that are desirable for economical reasons can be used without mechanical difficulty.

Light Loads and Overloads—The Curtis turbine is governed by changing the number of nozzle sections in flow, and the efficiency of the machine is therefore about the same under one condition of load as under another, except that friction, windage and generator losses tend to reduce slightly the light-load efficiency. Consequently, the efficiency of these turbines at light load is superior to that of turbines of any other type, and with high overloads turbines of the Curtis type are operated without by-passing steam and without loss of efficiency. These qualities give the Curtis turbine a much higher efficiency under average operating conditions than can be obtained from any other type of engine, assuming equal full-load efficiency. The generators to be operated with the turbines are designed for large overloads, and the units are thus suited to effective operation under a very wide range of conditions.

Governing—The speed of these turbines with variable load is controlled by the automatic opening and closing of the original admission-nozzle sections, the number of nozzle sections corresponding to the load being kept always in flow. A centrifugal governor attached to the top of the shaft imparts motion

to levers which in turn work the valve mechanism. There is a number of valves, each communicating with a single nozzle section, or in some cases two or more nozzle sections. These valves are connected to long pistons, by which the valve can be opened or closed by steam. The motion of each of these pistons is controlled by a small pilot valve which is worked by the governor mechanism. The movement of the governor mechanism moves the pilot valves successively, and the main valves are opened or closed by the steam. The mechanism is simple and durable in its character, and imposes a very light mechanical strain upon the centrifugal governor. By suitable adjustment, almost any degree of accuracy in speed control is obtainable.

THE MANUFACTURE OF STEAM TURBINES

The manufacture of steam turbines presents many problems that differ from those connected with the manufacture of steam engines, each particular type of turbine necessitating a special shop equipment suitable for its manufacture, the class of work and the problems differing so materially. One of the matters of first importance in the manufacture is perfect balancing of parts and uniform thickness of metal.

The various shops of the manufacturers were visited.

DE LAVAL TURBINE

The shops of the De Laval Company are located at Trenton. This factory is a new one, equipped with modern machinery and tools, and laid out so that each part of the turbine is separately made from jigs and gauges and returned to the storeroom and assembled from stock. A very comprehensive system of inspection has been adopted by which each piece is examined and measurements checked by standard gauges and after approval by the inspector is turned into stock in the storeroom. Each machine is tested at its rated load.

All of the material is ordered under specifications of the company and tested, special care being given to the quality of the material entering into the manufacture of the machine. The workmanship on both the turbine and the pumps is very high-class, all of their bearings, shafting and gearing being ground to fit. Its shop practice admits of very rapid filling of orders,

as the majority of the parts of the machine are held in stock, the bed plates and casing castings practically limiting the time of completion of any machine.

PARSONS TURBINE

At the Westinghouse Machine Company's works in Pittsburg, very marked advances in the shop equipment and improvements in the detail of construction of the turbine have been made within the past year. All of the material entering into the manufacture of the turbine is carefully tested before being worked. The turbine has ample clearances so that the cover and shaft may be removed with ease. A filling piece of mild steel is now used between the buckets, which are also caulked in position.

Buckets are made from hard-drawn brass, the shape being given to the rod in drawing, and the rod is cut off at the proper length for each size of turbine. After the casing has been rough-machined, it is heated several times with live steam so as to eliminate any local stresses, such that no further distortion is likely to take place after the final machining. The joint between the two halves of the casing is scraped to fit so that no packing is necessary. After the machine is assembled it is tested at full load and from 25 to 50 per cent overload. The thrust bearing is then adjusted and the machine is ready for shipment.

All of the work used on the turbine is of a very high class, and the machine as built should give satisfactory service both as to operation and low cost of repairs.

CURTIS TURBINE

This turbine is manufactured at the works of the General Electric Company, Schenectady, New York, and Lynn, Massachusetts. Large shops have been erected exclusively for the manufacture of turbines. The shop equipment consists of a large number of special machine tools designed to cut the buckets. These buckets are made in three styles: first, the buckets are cut in the periphery of a steel disc; second, the buckets are cut in sections and attached to a steel disc; and third, the buckets are cast of bronze and attached to the steel

disc. The first class is used in the small sizes; the second and third in the larger sizes of turbines. So far as the company has been able to determine, there is no difference in the life or efficiency between the cast-bronze and the steel buckets. There is less machine work on the bronze buckets, but the material is more expensive, and is adopted principally because it reduces the time of manufacture. Each disc is machined all over and carefully balanced before being assembled. The nozzles are cast in the case and are usually finished by chipping and filing. On account of the slower speeds of the Curtis turbine and its vertical shaft, the flexible bearing is not considered necessary.

Governors—A different form of governor has been adopted for each of the three types of turbines. The De Laval governor is a plain throttle governor driven from the gear shaft, the weights being mounted on knife edges. The valve is double-seated. It is held closed by a spring, and the governor rod is not directly connected to the valve rod, but the stub end comes in contact with the valve lever controlling the position of the throttle valve. In the event of the turbine speeding beyond the predetermined limit of speed, the governor opens an air valve on the exhaust side in order to act as a brake on the turbine wheel when running condensing.

In the Parsons type of governor, the governor shaft is kept constantly in motion and steam is admitted in a series of puffs, the lengths of these puffs varying from very short periods at light load to practically continuous admission of steam at overloads. The turbine is also provided with an emergency valve of the piston type, which trips and cuts off steam in the event of its speeding beyond safe limits. The governors of the Parsons and De Laval type are tested by instantaneously throwing full load off and on, the governor in both cases behaving admirably. In fact, the time involved can not be detected between the opening of the switch and the practical closing of the steam valve on the turbine. The speed variations on the Parsons turbine did not exceed two per cent, and on the basis that is customary in engine practice of two per cent above and below, they were within the limit. The variations in speed of the De Laval turbine were even better.

The system of governing on the Curtis turbine consists of varying the number of nozzles and the length of time that the nozzle is open on the first stage. The governor is of the fly-ball type, located on top of the turbine. A copper band attached to a band wheel on the governor shaft operates a drum on which are mounted a number of segments which operate fingers carrying contact points which close an electro-magnetic circuit operating a pilot valve which in turn operates the valve on the nozzles. This governor is sensitive and will control the machine within two per cent. At light load a single valve will admit steam to a nozzle at intervals, and, as the load increases, the number of nozzles open will increase in proportion to the load; generally one nozzle will be opening and closing constantly. The combination of electric steam control of the valves has been criticized and a mechanical control is also furnished. We have a further criticism to offer in that the valves can not be operated by hand, and there is no means of readily determining whether a valve is open or closed. In the event of one or more valves sticking in the open position, the turbine at light loads would run away, depending upon the emergency stop to shut the machine down. The shutting down of the machine would in many cases be very objectionable under these conditions, and this feature is now receiving the attention of the company. We have been informed by the company that the valve is now being made with the mechanism outside of the steam chest, in view of the attendant, and it may be operated by hand.

Wearing of Buckets—Your committee has endeavored to obtain information regarding the wearing of the buckets. It is acknowledged by the manufacturers that the buckets do wear. We have been, however, unable to find any case in which the wear of the buckets is a serious matter. It would appear that the excessive wear is due to two causes: first, defective metal, and second, moisture in the steam. We do not believe, however, that the wearing of the buckets will be a serious item of maintenance cost, and the buckets can be renewed in all of the types of turbines.

Superheated Steam—All of the manufacturers of turbines advocate the use of the highest superheat of steam, the reason being the apparent greater economy of the turbine. The

objections to using highly superheated steam are the difficulties in operating superheaters for high superheat and the additional expense involved in the cost of installing and operating the plant. It would appear from our investigations that the gain in superheat in turbines is almost parallel with that of a steam engine, and that there is a very decided advantage in using superheat even as low as 60 degrees, and from 60 to 150 degrees can usually be obtained without separate superheaters. This insures dry steam in the turbine and obviates the cutting of the bucket due to moisture.

Generators—Generators for turbines have been specially designed both by the Westinghouse Electric and Manufacturing Company and by the General Electric Company. In certain sizes of units the economical speed of the turbine imposed conditions that were very severe and apparently at variance with an efficient generator, types of generators designed for reciprocating engines not being suitable for this purpose. The difficulties that had to be overcome in the design of a turbine generator were: first, mechanical stresses set up by the high speed of the revolving part; second, providing suitable space for the conductors and the insulation and preventing their movement or rubbing against each other; third, the ventilation of the machine. The conditions changed so materially with the various sizes of units that a number of different designs have been tried. The generator difficulties have undoubtedly interfered materially with the more rapid development of the turbine. The problem, apparently, was simpler in the design of the alternating-current generator than in direct-current generators, as the field could be made the revolving element. The principal difficulty in the design of direct-current generators was the inherent structural weakness of the commutator when operating at high speed.

The Westinghouse Electric and Manufacturing Company has developed a revolving-field type of alternating-current generator of unique mechanical construction, which very satisfactorily fulfills the requirements of Parsons' turbine. It has also developed a direct-current generator for the smaller sizes; the commutator used being grooved, in order that a greater surface may be obtained from a minimum length of bar. One of these machines with the grooved commutator was in opera-

tion when your committee visited Pittsburg; there was no sparking of the brushes, the commutator was in excellent condition, and the machine was apparently giving very satisfactory results.

The General Electric Company has constructed a revolving-field type of alternating-current generator of good mechanical construction. The generator problem of Curtis turbines is simplified on account of the slower speeds of the turbine. In the direct-current generator the same difficulty is present in the commutator, and a commutator has been designed with an insulated wire binding around the centre of the bars. It would appear that there is difficulty in obtaining direct-current generators except in the smaller sizes to operate on lower voltages than 220 volts, on account of the difficulty of commutation of a greater output of current, with a reduction in voltage with the small practical length of bar. For 500 volts and over the commutator construction can be made satisfactory.

Tests—A test was conducted on a 400-kw Parsons turbine at the works of the Westinghouse Machine Company at Pittsburg. The unit consisted of a Parsons parallel-flow turbine directly connected to a two-phase, revolving-field, 60-cycle, alternating-current generator made by the Westinghouse Electric and Manufacturing Company. This was a commercial set, and the machine was delayed in shipment in order to allow the test to be made. Steam was taken from a separate superheater regularly used to supply superheated steam to the steam piping in the testing-room. The set was tested under its usual running conditions and at loads varying from 25 per cent overload, or 500 kilowatts, to 100 kilowatts and no load, *viz.:* 500, 400, 300, 200 and 100 kilowatts. The period of each test was one hour, and the load was maintained as nearly uniform as practicable for that time. Readings were taken at five-minute intervals, in order to obtain the corrected load for one hour. This load was obtained by means of water rheostats, and intervals of 20 minutes were allowed between each test, in order to adjust the rheostats and other apparatus prior to the starting of the next test. The first test was made at 500 kilowatts. A surface condenser was used, with independent air and circulating pumps. Excitation was obtained from a small turbine directly connected to a direct-current

generator. Water from the condenser was weighed in tanks, mounted on platform scales, and a three-way valve was so arranged that the water could be discharged into either tank, allowing continuous readings to be taken during the operation of the turbine; the hot well was provided with a gauge glass and was so calibrated as to check any errors due to water in the system of piping and condenser.

The condenser was tested for leakage at the end of the test. The electrical instruments, thermometers and gauges were calibrated before the test was started. After these tests were completed, full load was thrown off and on instantaneously, to test the governor. Its behavior was all that could be desired. The variation in speed of the turbine shaft was within two per cent, and the rise in voltage of the generator was within five per cent. The turbine was in continuous operation over ten hours, and during that time did not require any attention from the operator, demonstrating the automatic feature of the machine. The attached sheets give the detailed results of this test.

It was the intention of the committee to make tests on two or three different sizes of turbines of the Parsons and Curtis type at the works of the manufacturers. This was found to be impracticable, on account of the fact that the only machines available were machines on order, the shipment of which could not be delayed to permit of these tests. A test was made at Schenectady on a 2000-kw, four-stage Curtis vertical turbine directly connected to an alternating-current revolving-field generator. This test was conducted by experts appointed by the General Electric Company, one of whom was appointed as a representative of your committee. A number of engineers were also invited to be present to witness the test. The object of the test was to determine the efficiency at various loads. Two of the tests were interrupted on account of failures of the auxiliaries. A surface condenser was used and the water from the surface condenser was weighed in a tank mounted on a platform scale, the air and water pumps being independent and driven by motors. Causes for interruptions were due in one case to failure of the air pump and in the other case to interruptions in service supply to electric motors. The load was applied by means of a water rheostat and was

kept as nearly uniform as practicable during the time of the test. Five-minute readings were taken, in order to check the load. All of the instruments, gauges and thermometers were checked, previous to the test, in the company's laboratory. Various officials of the company expressed the opinion that the results were not so good as they had obtained in previous tests. The results of this test are attached. We have also received from the General Electric Company copies of results obtained from the same machine quite recently. These tests were made by the company under similar conditions to the test in question.

The large number of turbines now being installed at central stations will readily permit of accurate tests being made under their operating conditions, which will determine fully the actual advantage of the turbine over the reciprocating engine. From the tests, however, that have been made it has been clearly proven that the steam turbine is more economical than the reciprocating engine of similar sizes.

DEMAND FOR TURBINES

The very widespread interest that has lately been aroused in steam turbines appears to be general throughout the country. Engineers in the East, in the West and in the South are showing a keen interest in this subject. It would appear that this type of engine, used by the ancients and experimented with by most of the prominent engineers, will soon supplant its rival, the reciprocating engine. A number of large engine builders are now devoting their attention to the construction of steam turbines; notably, the Allis-Chalmers Company, now preparing to manufacture turbines of the Parsons type. Many of the ablest steam engineers are also associating themselves with the manufacture of steam turbines; indicating that, in the judgment of these experienced manufacturers, the demand for turbines will exceed the demand for reciprocating engines. The number of orders that have been received by the manufacturers is a further indication of the preference for the steam turbine over the reciprocating engine. This condition, as you will note, is similar to the advance being made in Europe and the active interest that all of the manufacturers have taken in its development.

IMPROVEMENTS

There is also a great deal of experimenting on other types of turbines, and improvements in existing types, being done. The Westinghouse Machine Company has recently added an additional governor to its turbine, to take care of the heavy overload, which admits high-pressure steam at an intermediate point in the turbine, thus increasing its capacity, either for heavy overload or when being operated non-condensing. This feature was formerly taken care of by a valve controlled by hand. This has the effect of making the machines automatic, under a wider range of control, and improves the economy slightly.

The General Electric Company is paying special attention to the valves controlling the nozzle openings, and is at present engaged in the design of a number of different forms of valves and controlling mechanism, each of which will be capable of being applied to existing turbines of its design. The De Laval Company has been engaged during the past two years in developing a type of turbine suitable for larger sizes, and in Europe Stumpf, Rateau, and others who are associating themselves with the larger manufacturing companies and other engineers, are giving very active attention to this subject.

ATTENTION

In the operation of turbines the class of attendant materially changes. The machine being practically automatic, it requires the minimum of attendance, and necessitates a man who is constantly watchful, but does not become fretful with the easy position. The engineer usually employed on reciprocating engines frequently becomes disgusted with the operation of the steam turbine unless he has an opportunity to give some attention to the auxiliaries. It seems to be constitutional with him to want to use a wrench and have a number of bearings to watch and handle.

ADVANTAGES

The advantages of the turbines can be summed up as follows:

Higher efficiency.

Lower first cost.

Minimum amount of labor.

Lower depreciation and maintenance.

Small amount of oil required.

Freedom from vibration.

Lower cost of buildings and foundations.

Uniform rotation, which is especially desirable for operating alternating-current generators in parallel.

The machine can be started as quickly as can the reciprocating engine.

Can be governed as closely as the steam engine.

Full load can be thrown on or off instantaneously without in any way endangering the turbine.

Condensed steam is free from oil so that the water can be returned to the boilers, this being especially valuable where a bad feed water is used.

Simplicity of packing.

Small number of bearings.

All parts can be made to gauges.

Minimum amount of fittings and ease in renewing the parts.

It operates equally well condensing or non-condensing.

Freedom from breakdowns owing to water in the steam.

Relatively small size of all parts, insuring more perfect material.

High economies at light loads.

Good regulation of generator.

The depreciation of the turbine has not thus far been fully determined. We feel confident, however, that it will be less than that of the reciprocating engine.

The committee has been in communication with the following users of steam turbines. We append the list of users so that any members may communicate with them directly should they desire:

LIST OF USERS OF STEAM TURBINES TO WHOM LETTERS WERE SENT

Yale & Towne Mfg. Co., Stamford, Conn.

B. F. Goodrich Co., Akron, O.

Consolidated Rwy. & Lighting Co., Wilmington, N. C.
Johnson Harvester Co., Batavia, N. Y.
Roslyn Lt. & Power Company, Roslyn, L. I.
S. D. Warren & Co., Cumberland Mills, Me.
Saco & Pettee Mach. Shops, Middleford, Me.
Citizens Lt. & Pwr. Co., Johnstown, Pa.
City of Columbus, Columbus, O.
Atlantic Mills, Providence, R. I.
Portsmouth Street R. R., Portsmouth, O.
Anderson Municipal Light Plant, Anderson, Ind.
Cleveland, Elyria & Western, Cleveland, O.
Chicago Edison Company, Chicago, Ill.
San José Ry. & Light Co., San José, Cal.
Port Huron Light & Power Co., Port Huron, Mich.
Narragansett Elec. Ltg. Co., Newport, R. I.
D. L. & W. R. R. Co., Scranton, Pa.
Nashua Lt. & Power Co., Nashua, N. H.
Chattanooga Lt. & Power Co., Chattanooga, Tenn.
Binghamton Lt. & Power Co., Binghamton, N. Y.
Macon Ry. & Light Co., Macon, Ga.
Laclede Lt. & Power Co., St. Louis, Mo.
United Gas & Electric Co., Dover, N. H.
Winona Ry. & Light Co., Winona, Minn.
Hartford Elec. Light Co., Hartford, Conn.

The following questions were asked these users of turbines:

Location of plant.
Number of turbines in use.
Make of turbine.
Use to which turbine is put.
Principal dimensions.

Weight	Turbine Generator
Type	Generator Condenser
Capacity	Full load Guaranteed percentage overload with rise in temperature

Efficiency:
- 50 or 25 per cent overload
- Full load
- 75 per cent load
- 50 per cent load
- 25 per cent load

Is superheated steam used? If so, state the amount of superheat in degrees Fahrenheit.

Type of governor—Please state if one or more governors are used, and whether the governor is mechanical or electrical.

Percentage of variation in speed from no load to full load and with sudden changes of load.

Please state the interruptions to service due to any cause in the turbine and state the cause.

Please state the time required between the delivery of turbines on foundation and the placing of same in commercial use.

What advantages does the steam turbine possess in your service not possible, or not commercially obtainable, with the reciprocating engine? The intent of this last question is to obtain a line upon the practical rather than the theoretical value of the turbine from the central-station standpoint.

Replies were received from a large number of users. Those who have had the turbine in use for some time strongly indorse its operation and efficiency; and the interruptions that they state they have had were due to mechanical defects that were easily remedied.

The time given for erecting turbines in sizes varying from 400 to 1500-kw is from two to four weeks, depending upon the facilities for handling the heavy parts in each case during erection.

In regard to the operation of the step bearing of the Curtis turbine, there has been no objection from the users, and we have been unable to locate a case in which it has given trouble. We did not receive any unfavorable replies from the users regarding the operation of the turbine or any of its parts.

Mr. Fred Sargent has made a very exhaustive investigation of the steam turbine, and of the manufacture of the various

types in Europe. His report is appended and will be published in the proceedings.

The committee desires to extend its thanks to the manufacturers and users of túrbines who very kindly assisted it in procuring the information contained in this report.

Respectfully submitted,

Committee, W. C. L. EGLIN, Chairman,
FRED SARGENT,
A. C. DUNHAM.

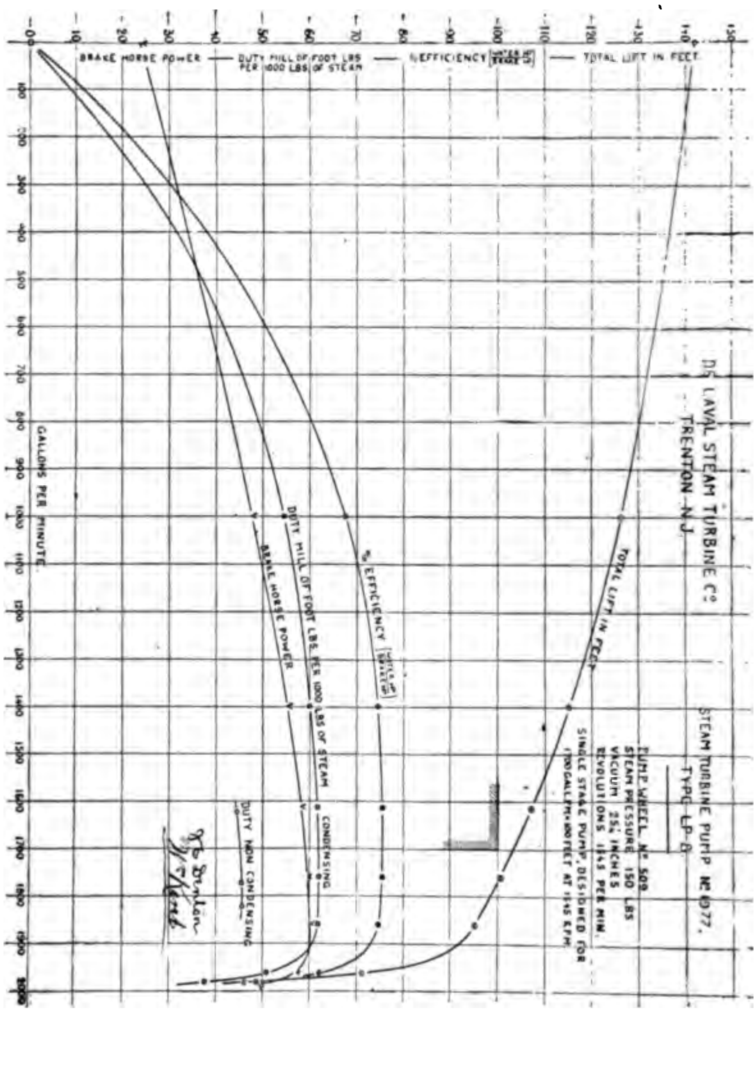

DE LAVAL STEAM TURBINE Co
TRENTON N.J
STEAM TURBINE PUMP
TYPE LP-D
BRAKE HORSE POWER
DUTY MILL OF FOOT LBS PER 1000 LBS OF STEAM
% EFFICIENCY
TOTAL LIFT IN FEET
GALLONS PER MINUTE
CONDENSING
DUTY NON CONDENSING

FIG. 14

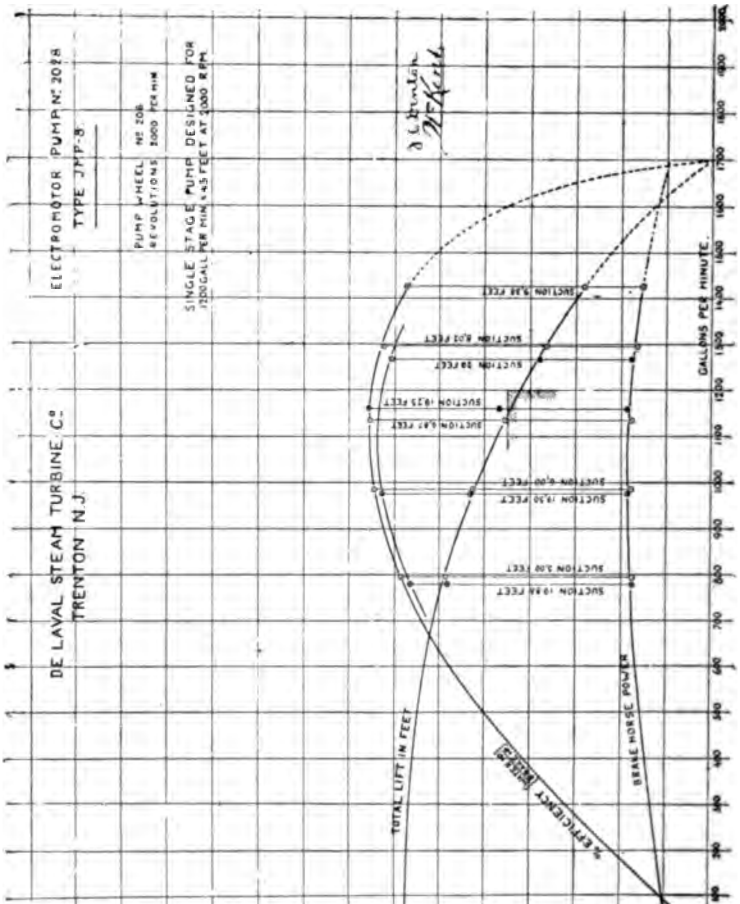

DE LAVAL STEAM TURBINE Co
TRENTON N.J.
ELECTROMOTOR PUMP No 2028
TYPE JMP-8
TOTAL LIFT IN FEET
% EFFICIENCY
BRAKE HORSE POWER
GALLONS PER MINUTE

FIG. 15

SUMMARY OF TESTS ON A 400-KW WESTINGHOUSE-PARSONS STEAM TURBINE

	Test No. 7	Test No. 8	Test No. 9	Test No. 10	Test No 11	Test No. 12
	¼ Overload	Full Load	¾ Load	½ Load	¼ Load	No Load
Steam pressure at throttle, gauge	147.7	148.2	147.7	155.5	156.6	154.2
H P. inlet pressure lbs. gauge	120.9	92.8	71	49.5	30.8	....
Vacuum in L.P. outlet by mer. col.	27.35	27.47	27.4	27.4	27.35	27.4
Vacuum referred to 30" barometer	28.14	28.16	28.4	28.04	28	28.05
Barometer	29.21	29.31	29.31	29.31	29.31	29.31
Temperature at superheater outlet	666.6	696.6	698.6	697.3	696.3	642.6
Superheat at superheater	300.9	330.8	333	328.7	327	274.1
Temperature at throttle	540.6	547.5	527.6	502.2	466.9	425.6
Superheat at throttle	176.1	12.7	163.1	133.9	98.1	57.9
Speed	3507	3536.4	3549	3567.9	3586.8	3612
Load in kilowatts	504.6	408	300.6	199.6	99.98	....
Load in e.hp	676.4	547	402.9	267.6	134	....
Total net lbs. steam condensed	8624	7032	5538	4036	2670	916
Lbs. steam per e.hp-hour	12.7	12.8	13.7	15.1	19.93	....
Lbs. steam per kw-hour	17.09	17.24	18.42	20.22	26.70	. ..

SUMMARY OF TESTS ON A 2000-KW CURTIS STEAM TURBINE

	Test No. 1A	Test No. 1B	Test No. 2	Test No. 3	Test No. 4	Test No. 5
	⅓ Overload	⅓ Overload	1/10 Overload	Full Load	½ Load	⅓ Load
Throttle pressure	174.2	173.8	176.5	165.5	177.5	148.5
" temperature R.	591	565.7	565	618.5	606	565
" " L.	591	565.7	554	433	426	418
" superheat R.	220.7	195.2	193	252	234	207.5
" " L.	220.7	195.2	182	67	54	60.5
1st stage pressure	54.5	....	46.5	48.8	26.5	12
2d " "	23.3	....	15	13.4	7.1	5.4
" " temperature R.	379	....	370	373	371	320
" " " L.	327	....	317	322	315	262
" " superheat R.	138	....	157	166	193.5	155
" " " L.	86	....	104	116	137.5	97
3d " pressure	4.45	....	4.2	3.7	2.9	2.2
" " temperature	269	....	266	259	141	215
" " superheat	112	....	111	113	72	85
Condenser pressure	.8	....	.72	.64	.54	.94
" temperature	105	....	103	93	124	115
" superheat	10	....	7	5	42	15
Load, kw-hours	2754	2746.8	2203.2	2016	99.6	635.7
Lbs. steam per kw-hour	15.57	16.37	15.46	15.24	16.38	20.94

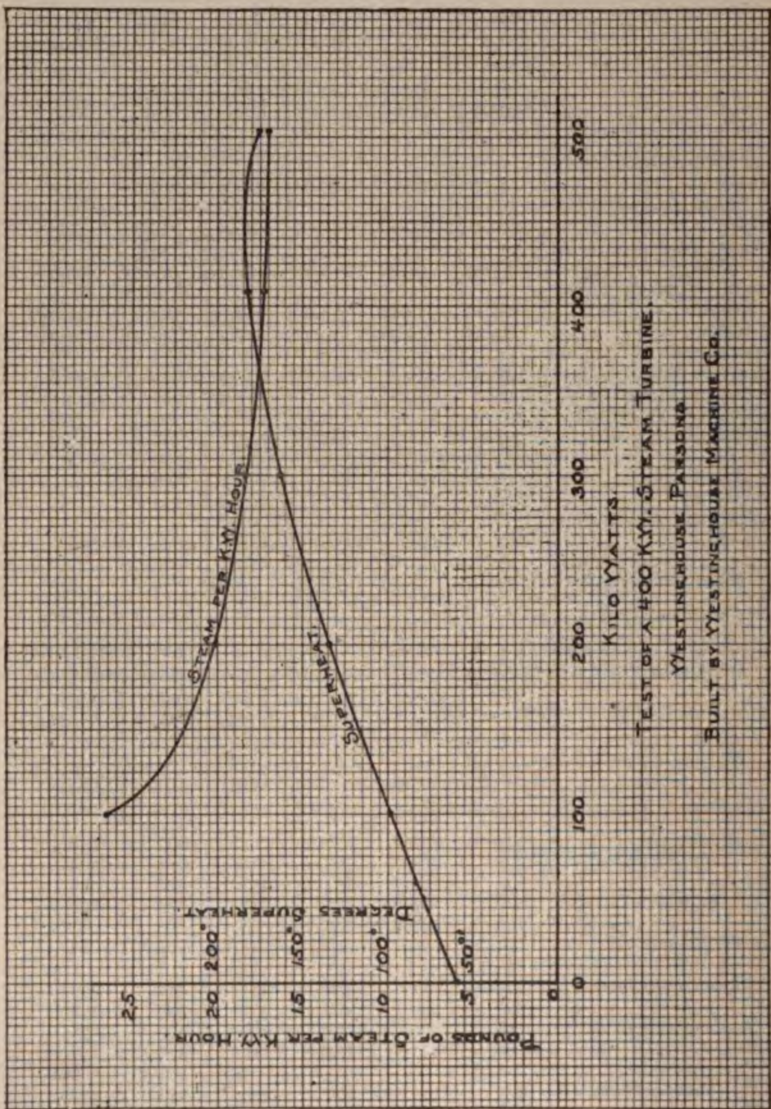

Steam per K.W. Hour
Superheat
Degrees Superheat.
200°
150°
100°
50°
25
20
15
10
5
0
0
100
200
300
400
500
Pounds of Steam per K.W. Hour.
Kilo Watts.
Test of a 400 K.W. Steam Turbine.
Westinghouse Parsons.
Built by Westinghouse Machine Co.

FIG. 16

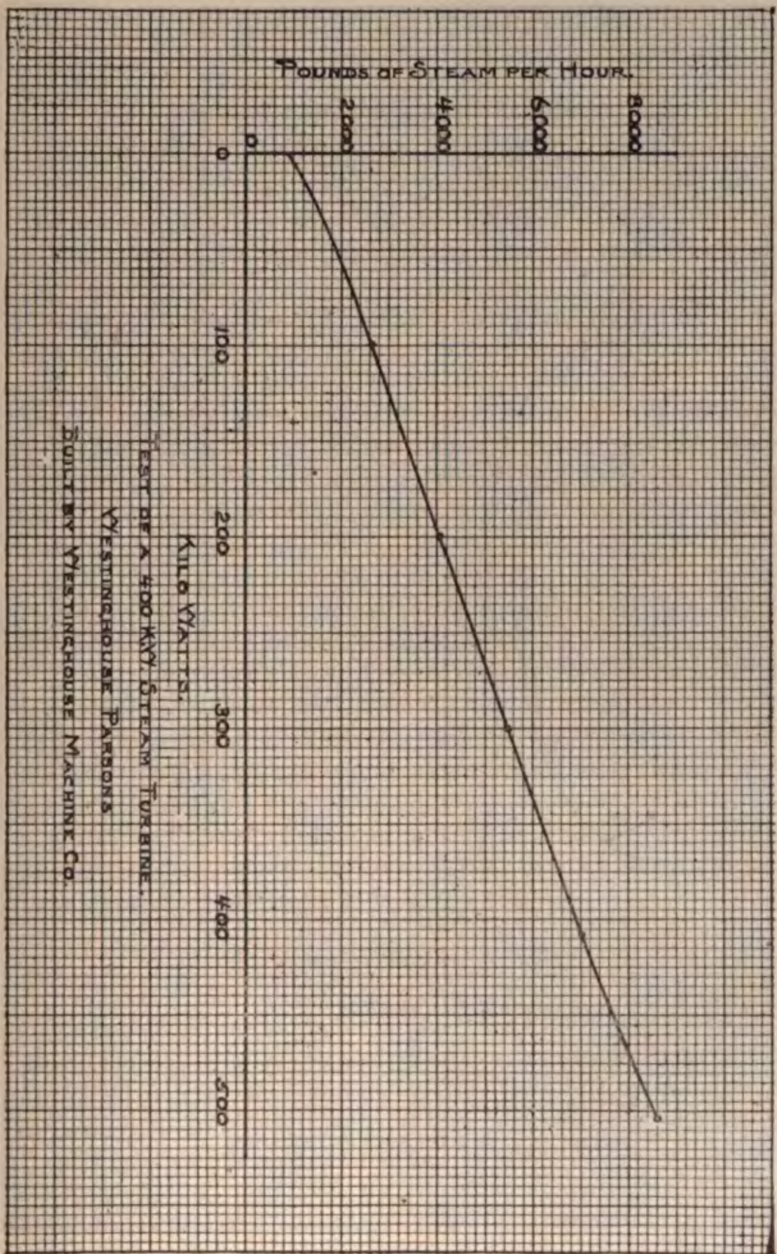

POUNDS OF STEAM PER HOUR.
0
2,000
4,000
6,000
8,000
0
100
200
300
400
500
KILO WATTS.
TEST OF A 400 KW. STEAM TURBINE.
WESTINGHOUSE PARSONS
BUILT BY WESTINGHOUSE MACHINE CO.

FIG. 17

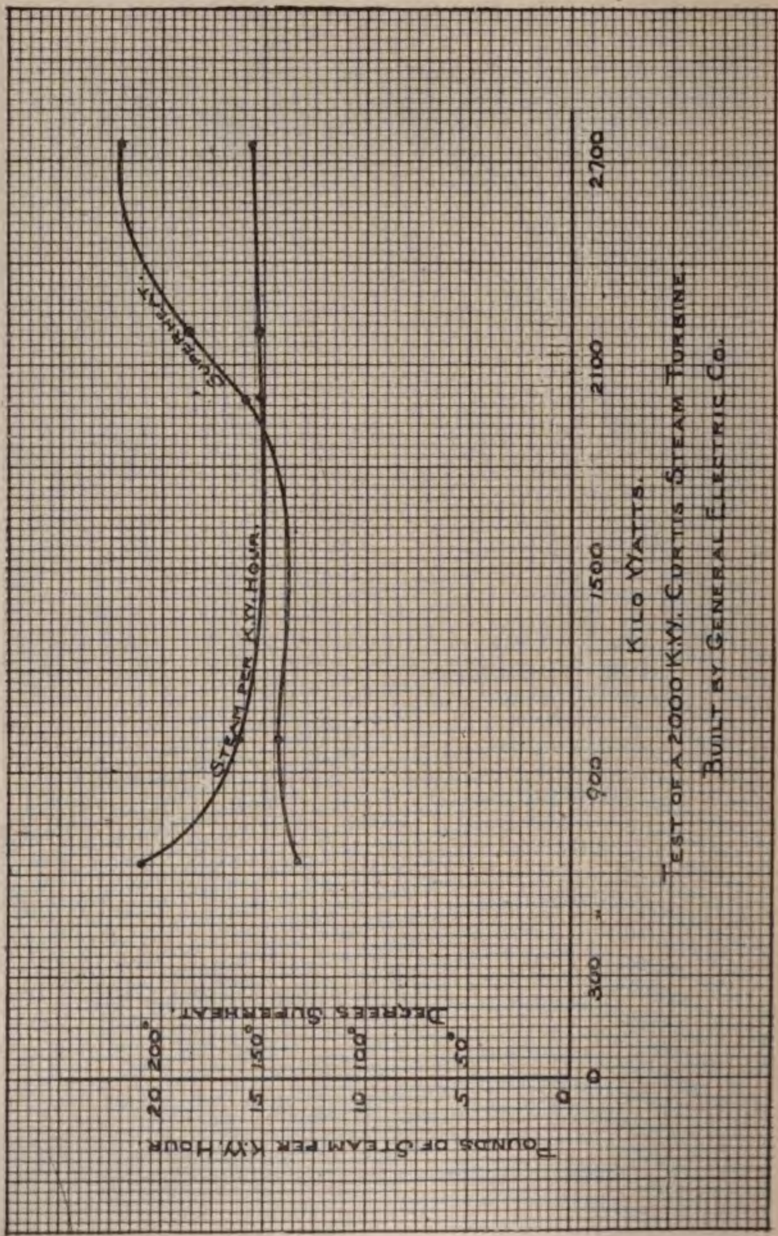

Pounds of Steam per K.W. Hour.
0
5
10
15
20
50°
100°
150°
200°
Degrees Superheat.
Steam per K.W. Hour.
Superheat.
0
300
900
1500
2100
2700
Kilo Watts.
Test of a 2000 K.W. Curtis Steam Turbine.
Built by General Electric Co.

Fig. 18

REPORT SUBMITTED BY MR. SARGENT

MR. WM. C. L. EGLIN,
Chairman Committee on Steam Turbines,
National Electric Light Association.

DEAR SIR: I have the honor to submit herewith some information about the steam-turbine situation in England and on the continent of Europe, gathered largely from personal observation.

The situation from a broad and general point of view indicates that the steam turbine is now generally recognized as being a superior machine to the reciprocating steam engine for driving generators for central-station work. Its success in this direction during the last few years has been phenomenal, and at the present time it is very generally used both for extensions to existing stations and for new work. The largest and most important central stations under construction are being equipped with this type of steam motive power, and one of those in which the machinery is now being installed is to contain ten 5000-kw units.

Although five different types of steam turbines are being manufactured, and at least one more is developed and ready for manufacture, the important and truly successful central-station work has been done and is being done up to the present time largely by one type, namely, the Parsons.

The five types manufactured are the Parsons, De Laval, Rateau, Riedler-Stumpf, and Curtis, and the one that is developed ready for manufacture is the Zoelly.

THE PARSONS STEAM TURBINE

In 1884, the Honorable C. A. Parsons, F.R.S., after numerous experiments brought out his first steam turbine, which ran for many years and is now in the South Kensington Museum, at London. It was coupled direct to a high-speed dynamo and developed about 10 horse-power at 18,000 r.p.m.

Larger and more economical turbines were successfully constructed, and in 1888 the first condensing turbine was designed, but, owing to various difficulties, such a turbine was not constructed until 1892, when it was tested by Professor

Ewing, F.R.S., in view of the proposal to use steam turbines for the lighting of Cambridge. This turbine was of 200 horse-power at a working speed of 4800 r.p.m., and consumed 27 pounds of steam per kw-hour, which is equivalent to 16 pounds of steam per i.hp-hour.

In 1900, two alternators, each of 1250-kw capacity, were made for the city of Elberfeld, Germany. The turbines were of the tandem type, consisting of high and low-pressure cylinders, and ran at 1500 r.p.m. The dynamos were four-pole and supplied single-phase current at 400 volts and 50 periods. The steam consumption with a slight superheat was 18.8 pounds per kw-hour at full load, or 11.9 pounds per i.hp, including the power required to drive the air pumps and exciter. These dynamos run perfectly in parallel with the 1500-hp Sulzer engines, which are coupled to a 1000-kw Brown-Boveri alternator, running at 83 r.p.m. In fact, the turbines steady the reciprocating engines even when the latter are running on traction load.

In June, 1903, turbines for driving dynamos had been built in England and on the Continent under Parsons patents aggregating upwards of 250,000 horse-power and in sizes up to 5000-hp. Consumptions of steam as low as 15.8 pounds per kilowatt, or about 9.8 pounds per i.hp-hour, have been recorded when using steam at 142 pounds pressure delivered to the turbine superheated 120 degrees Fahrenheit.

The orders on hand at the present time in England and on the continent of Europe for steam turbines of the Parsons type for driving dynamos amount to over 200,000 kilowatts in sizes up to 5000-kw and approximately 200,000 horse-power, for marine work.

The lowest steam consumption recorded is 14.74 pounds of steam per kw-hour on a 3000-kw Brown-Boveri-Parsons turbo-alternator at Frankfurt-on-the-Main, Germany, operated at 2995 kilowatts, with steam at 138.5 pounds per square inch gauge pressure and superheated 235 degrees Fahrenheit. This includes power for exciting and condensing.

The complete test is presented herewith:

Pressure of Steam Above Atmosphere at Stop Valve	Superheat at Stop Valve	Vacuum in the Turbine Cylinder Bar, 30 Inches	Revolutions per Minute	Load	Steam Used	
Pounds per Square Inch	°F.	Inches Mercury		Kilowatts	Pounds per Hour	Pounds per Kw-hour
138.5	235	27	1,350	2,995	44,200	14.74
170.5	187	27.50	1,350	2,518	39,300	15.59
142	120	27.20	1,350	2,600	41,200	15.80
139	114	27.20	1,360	2,600	41,400	15.90
168.5	184	27.90	1,350	1,945	30,800	15.64
146.5	120	27.60	1,360	2,000	32,600	16.30
137	101	27.40	1,350	1,442	25,400	17.00
138	52	25.70	1,350	[illegible]	18,700	29
142	30	28.30	1,350	[illegible]	4,700	....
142	30	28.30	1,350	...	3 560	....

Steam turbines of the Parsons type are being manufactured by the following concerns: C. A. Parsons and Company, Heaton Works, Newcastle-on-Tyne, England; Brown-Boveri Company, Baden, Switzerland; The British Westinghouse Company, Manchester, England; Richardson, Westgarth and Company, West Hartlepool, England; Willans and Robinson, Rugby, England.

The turbine being manufactured by Willans and Robinson, Rugby, England, is the same as that being manufactured by the Allis-Chalmers Company in this country, and, while it is of the Parsons type, it is being manufactured under what are known as the Fullagar patents. The difference between this and the regular Parsons type consists mainly in a new method of putting in the blades. In the regular Parsons machine the blades with a distance piece between each are caulked separately in a slot prepared for the purpose. By the Fullagar method the blades are first built up in a framework forming a half circle and then the frame is caulked in a slot prepared for the purpose. While I saw several machines of this type in course of construction of sizes including 5000-kw, none was yet ready for operation.

THE DE LAVAL STEAM TURBINE

The present type of De Laval steam turbine was first made public about the year 1893, when it was exhibited at the World's Columbian Exposition at Chicago. It is made in sizes up to

300-hp regularly, and I believe has been constructed as large as 500-hp. Up to the present time upwards of 50,000 horse-power has been constructed, principally for driving electric generators, rotary pumps, and fans.

The speed of this machine varying from 30,000 r.p.m. in the five-hp size to 10,000 r.p.m. in the 300-hp size necessitates the use of intermediate gearing to reduce the speed to the generator, pump or fan to which it is attached. The best steam economy recorded for this type of machine was obtained during tests made by Messrs. Dean and Main, of Boston, on a 300-hp machine, as follows:

SATURATED STEAM

Load, Horse-power	Steam-gauge Pressure, Pounds per Square Inch	Vacuum, Inches	Steam per Brake Hp-hour
333	206.4	26.6	15.17 pounds
285	207.3	26.8	15.56 "
195	207.6	27.35	16.54 "
119	201.5	28.1	16.40 "

SUPERHEATED STEAM

Load, Horse-power	Steam-gauge Pressure, Pounds per Square Inch	Superheat, Degrees Fahrenheit	Vacuum, Inches	Steam per Brake Hp-hour
352	207	84	27.2	13.74 pounds
298.4	207.4	64	27.4	14.35 "
196.5	201.5	13	27.4	15.53 "

I understand that the De Laval Company, of Stockholm, Sweden, is developing a new type of machine and that three turbines, each of 750-kw capacity, are under construction for an English plant.

The De Laval steam turbine is being manufactured by the following companies: Aktiebolaget de Lavals Angturbin, Stockholm, Sweden—Norway, Sweden and unoccupied territory; Societe De Laval, 48, Rue de la Victoire, Paris—France and colonies; the English De Laval Steam Turbine Company, Limited, Albion Works, Leeds, England—Great Britain and

Ireland, the British colonies, Egypt, China and Japan; Machine-bau-Anstalt Humboldt, Kalk bei Köln—Germany and colonies.

THE RATEAU STEAM TURBINE

The Rateau steam turbine dates from about 1894 and has been developed in two types.

(1) For utilizing low-pressure steam exhausted from non-condensing reciprocating engines.

(2) For ordinary boiler pressures.

The majority of the machines in operation are of 300 to 500-hp capacity, but one of 2700-hp is under construction for the Donetz Steel Works, Russia.

The total capacity in operation and under construction is stated to be about 30,000 horse-power, made up as follows:

Ship propulsion	6,200	horse-power
Electric generators	21,700	"
Turbo pumps	1,300	"
Turbo fans	800	"
	30,000	horse-power

The following table shows results of tests on a 300-hp low-pressure turbine driving two direct-current generators at the Bruay Mines, France:

Load, E.hp	Absolute Pressure, Pounds per Square Inch		Superheat, Degrees F.	Steam, Pounds per E.hp-hour
	Initial	Final		
255.2	12	2.22	68	40.2
265	12	2.22	68	39.7
265.3	12	2.22	69.5	38.6
323	14.35	2.57	64	38.9
331.5	14.35	2.61	64	37.9
271	12.8	2.32	74	40 7
311.7	14.7	2.78	85	40.5

The barometric pressure was 29.7 inches during the first five tests, and 29.9 inches during the last two.

A test of a 500-hp turbine, one of a set of three at the Pennaroya Mines, Spain, is stated to have given the following results:

	Quarter Load	Half Load	Full Load	Overload	Overload at 2400 R.p.m.
[illegible]	135	259	525	627	641
[illegible]	46.2	76.79	136.53	156.44	156.44
[illegible]	1.24	1.35	1.63	1.82	1.82
[illegible]	21.31	18	15.77	15.35	14.90

Speed, 2000 r.p.m.

[illegible] turbine is manufactured under license by the [illegible]:

[illegible] Bietrix, Leflaive and Company, St. Etienne; Saut-[illegible] and Company, Paris; Establissements Cail, Douai; [illegible] [illegible]onnaise, Paris.

[illegible]—Schuchtermann and Kremer Societé Balcke a [illegible] Dortmund.

Austria—Ateliers Archiducaux d'Vestron, Societé Skoda [illegible].

Switzerland—Oerlikon Works, Oerlikon.

Belgium—Societé des Produits, Flenu; Fonges de Gilly, Charleroi.

Russia—La Metallique, Ateliers de Gorlovka, St. Petersburg.

RIEDLER-STUMPF STEAM TURBINE

Several Riedler-Stumpf turbines have been constructed by the Allgemeine Elektricitats Gesellschaft, Berlin, Germany, principally for experimental purposes. The largest of these is a 2000-hp turbo-alternator erected at the Moabit central station, Berlin, where it has been put through exhaustive tests.

Some few of these machines of comparatively small size have recently been sold for the electrical equipment of some war vessels in the German navy.

In a paper read by Professor Riedler before the German Institution of Naval Architects November 19, 1903, a test of the 2000-hp turbine was given as follows:

Steam pressure	188 pounds gauge pressure
Superheat	187 degrees Fahrenheit
Vacuum	25½ inches
Steam consumption	17.6 to 19.6 pounds per kw-hour

THE CURTIS STEAM TURBINE

The manufacture of the Curtis steam turbine in Europe has been begun very recently, and although several orders are passing through the shops none has yet been completed.

This machine is being manufactured by the British Thomson-Houston Company, Rugby, England; by the French Thomson-Houston Company, Paris, France, and is about to be manufactured by the Allgemeine Elektricitats Gesellschaft, Berlin, Germany.

THE ZOELLY STEAM TURBINE

After some years of experimenting and the construction of several trial machines, Mr. Zoelly, of Escher, Wyss and Company, the famous turbine water-wheel builders of Zurich, Switzerland, has perfected a turbine of about 600-hp, direct-coupled to a dynamo. This machine is erected at the works of Escher, Wyss and Company, Zurich, and has been carefully tested by Dr. Stodola, of the Zurich Polytechnic, with the following results:

TEST OF ZOELLY TURBINE

These trials were carried out with a boiler pressure of 150 pounds per square inch and a vacuum of 93.5 per cent. In the superheated steam trials the temperatures were measured at the throttle valve—not at the machine. The steam consumption is per kilowatt at the poles of the dynamo.

The steam for operating the condenser is not included. It amounts to an increase of from 2.5 to three per cent.

I—Saturated Steam

No load, not excited, consumption per hour	646.9	pounds
No load, excited, " "	1023.9	"

Load			
80.1 kilowatts.	Steam per kw-hour	33	pounds
182.2 "	" " "	25.74	"
240.1 "	" " "	23.98	"
334.5 "	" " "	22.22	"
387.6 "	" " "	21.43	"

II—Superheated Steam

Kilowatts	Steam Temperature, Degrees F.	Superheat	Steam per Kw-hour
390.4	396	31 degrees F.	19.76 pounds
391.7	432	67 "	19 "

(Signed) Dr. A. Stodola.

Negotiations for the manufacturing rights for this machine for the continent of Europe have been completed and are in

the hands of a syndicate containing the following well-known names: The Siemens and Halske Company, Berlin; North German Lloyd Company, Bremen; Messrs. Krupp and Sons, Essen.

For those interested in a detailed technical description of these various steam turbines and in scientific information about the principles of construction of steam turbines generally, the writer recommends Dr. A. Stodolas' *Die Dampfturbinen,* published by Julius Springer, Berlin.

A translation of this valuable work is being prepared by Professor Loewenstein, of the University of Pennsylvania, and will be published by Van Nostrand Company, New York, about September or October of this year.

Respectfully submitted,

F. SARGENT.

PUBLICATIONS ON STEAM TURBINES

STEAM TURBINE—By Robt. M. Neilson, published by Longman, Green & Company, London and New York.

DIE DAMPFTURBINEN—A German work by Dr. A. Stodola. This is being translated and we are informed will appear in English within the next two months.

CURTIS STEAM TURBINE—Paper by W. L. R. Emmet, read before the Philosophical Society of Philadelphia.

CURTIS STEAM TURBINE—Paper by W. L. R. Emmet, read before the Engineers' Club of Philadelphia.

STEAM TURBINES—Paper by Francis Hodgkinson, presented before the Engineers' Society of Pennsylvania.

PRACTICAL NOTES ON STEAM TURBINE—Paper read before the National Electric Light Association, May, 1904, by Francis Hodgkinson.

NOTES ON THE OPERATION OF THE CURTIS STEAM TURBINE—Read by August H. Kruesi before the Association of Edison Illuminating Companies, September 8, 1903.

THE STEAM TURBINE FROM AN OPERATING STANDPOINT—By Fredk. A. Waldron, presented at the Saratoga meeting, June, 1903, before the American Society of Mechanical Engineers.

Also publications by Westinghouse Machine Company, General Electric Company, De Laval Steam Turbine Company.

THE PRESIDENT: I asked both the General Electric Company and the Westinghouse Electric and Manufacturing Company to prepare papers on this subject of steam turbines or to discuss them. Mr. Rice, of the former company, is here prepared to discuss the subject, and Mr. Hodgkinson, of the Westinghouse company, has prepared a paper upon it.

MR. FERGUSON: Mr. President and Gentlemen—I know that Mr. Eglin and his associates have spent a great deal of time during the year in preparing this report, and I therefore move that a vote of thanks be given them for the excellent report that they have presented.

THE PRESIDENT: I am very glad to put this motion. Mr. Eglin asked me to attend the meetings of this committee, and I have been able to do so. I know that they have performed an immense amount of work. It may interest you to know that in writing the presidential address on Saturday last I apologized for this report not being already in print, but I had to rewrite that portion of my address on Monday. To my surprise, copies of the printed report came here on Sunday. I do not see how the committee succeeded in doing its work so thoroughly and promptly. It deserves the greatest credit for having performed its duties so promptly and faithfully.

(Mr. Ferguson's motion was put and carried.)

THE PRESIDENT: We will now take up the paper "Practical Notes on Steam Turbines," by Mr. Francis Hodgkinson, of Pittsburg.

The paper, as follows, was read by Mr. Hodgkinson:

PRACTICAL NOTES ON STEAM TURBINES

It was long ago shown by Zeuner that the energy that may be theoretically extracted from a jet of steam is precisely the equivalent of the energy that would be given up by the same quantity of steam working between the same pressure limits expanding behind the piston of an ideal engine. By an ideal engine is meant an engine that has neither mechanical nor thermal losses. It is well known, of course, that the best steam turbines and steam engines fall considerably short of this ideal. A discussion of the theory of steam jets, nozzle shapes, bucket forms and the like, has hardly a place in this paper and it is intended to confine it to the more practical purposes of turbine work.

By means of a correctly formed nozzle, steam can be made to do work upon itself and convert all its energy into giving itself velocity. The jet constrained to impinge on suitably formed buckets can then be made to yield this energy just as in the case of a water turbine. The analogy between steam and water turbine is not, however, a strictly exact one, for the reason that, in the case of the former, two energy conversions take place; first, heat into energy of velocity; and secondly, velocity into work; while in the latter the conversion is kinetic only. The difficulties of turbine design lie in the fact that steam is a medium of low density, and consequently attains very high velocities with moderate pressures.

This comparison can readily be shown by comparing the energy of one pound of steam and one pound of water at 150 pounds per square inch gauge pressure; for example, discharging into a 28-inch vacuum, or one pound absolute pressure. The water will be theoretically capable of developing 379 foot-pounds of energy and will discharge with a velocity of about 156 feet per second. To deal with this velocity, the best speed of a wheel of the Pelton type, one foot in diameter, would be 1490 r.p.m., a very comfortable speed. On the other hand, the one pound of steam will correspondingly develop 250,000 foot-pounds of energy and will have a theoretical discharge velocity of over 4000 feet per second, which would necessitate a corresponding speed of 38,300 r.p.m.

SOURCES OF LOSS

The various losses incidental to steam turbines are in some respects different from those of a reciprocating engine, although, taken in the aggregate, they amount to closely the same percentage.

These losses may be itemized as follows:

First—The jet does not attain the maximum ideal velocity, because of friction of the walls of nozzles or passages.

Second—Frequently the speed of the buckets is too low with reference to the jet and the steam issues from the buckets with much residual velocity.

Third—Skin friction, due to high-velocity steam passing over the bucket surfaces. Skin friction, due to wheel discs and other exposed surfaces revolving in a more or less dense medium. Skin friction, due to water of condensation. This water is directly a result of adiabatic expansion.

Fourth—Leakage: the escape of steam from a cell of higher pressure to a cell of lower pressure.

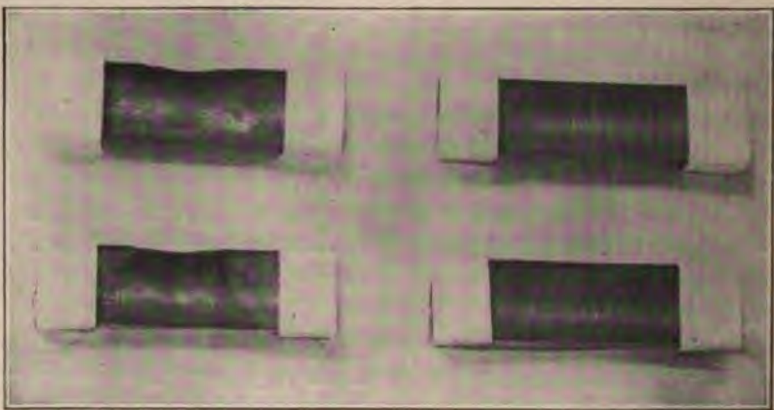
Fifth—Spilling, due to steam expanding from an orifice and missing the blade. This would be also in evidence if we were to conceive of a De Laval turbine being operated without a shroud around the blades.

Sixth—Eddies, due to badly formed buckets causing loss of energy and the steam to form eddies, disturbing the proper flow of the particles.

Seventh—Angle of nozzles and blades is always a source of loss except in a turbine strictly resembling a Pelton wheel. Since the nozzle and blades must make some angle with reference to the plane of motion of the buckets, the steam velocities therefore have a component parallel to the axis, which results in a loss similar to that of the first item.

The velocity of steam that may be attained by 150 pounds of steam discharging into a 28-inch vacuum is over 4000 feet per second and is approximately twice that of a rifle bullet. In view of this fact, it would seem desirable to avoid high steam velocities as much as possible, because of resulting frictional losses. Another reason is the erosive action of the steam with high velocities. This is quite serious when the steam is initially wet, due to foaming boilers. In this case, matters are generally made worse by the moisture carrying with it various kinds of solid impurities.

In this connection, the author lately had some Delta metal blades exposed to two steam jets, the one issuing from a diverging nozzle with 150 pounds boiler pressure behind it, and the other from a rounded orifice with one pound pressure. The size of the outlets of the two nozzles was the same in each case and the velocities were approximately 2900 feet and 600 feet per second, respectively. The blades were kept continuously exposed to the jets for 128 hours. Figure 1 shows their condition at the end of the test. A considerable amount of erosion will be observed on the blades subjected to the higher velocity.



Exposed for 128 hours to steam at 2900 feet per second velocity

Exposed for 128 hours to steam at 600 feet per second velocity

FIG. 1—SHOWING EROSION OF JET TURBINE BLADES

A rather curious feature, too, is that the erosion was maximum at the centre and also at the extreme edges of the jet. No attempt was made to observe the quality of the steam; the nozzles were merely connected to a steam pipe in the works.

TYPES OF TURBINES

The De Laval turbine forms the simplest type of turbine in so far as it consists simply of a set of nozzles and one revolving row of buckets only. For this reason it necessarily runs at high speeds, and gearing is essential to bring the speeds within practical limits.

THE STUMPF

A more recently developed turbine, the Stumpf, likewise utilizes these distinguishing elements of the De Laval turbine, with, however, a slight departure from this arrangement in the use of tangential nozzles with buckets of the Pelton form milled in the periphery of the wheel. These are slightly pitched from the shaft in order to provide metal for succeeding buckets. A characteristic of this form of turbine is the large wheel diameter employed, and it is in this direction that low shaft speeds are secured. For example, a 500-hp turbine with two discs five feet in diameter has been constructed and run at a speed of 3000 r.p.m. with a rigid shaft. In later forms of the Stumpf turbine, it has been sought to utilize a residual velocity of the steam leaving the buckets by redirecting it around a circular guide, so as to impinge again upon another set of buckets milled in the periphery of the wheel, alongside the other row. The steam jet after leaving the nozzle is, therefore, reversed 180 degrees twice before finally leaving the wheel.

COMPOUND SYSTEMS

On account of the difficulties of construction and losses attendant upon the use of high steam velocities, various methods of compounding have been proposed, the objective point of the compounding arrangement being a subdivision of total velocity among several stages, so that the working velocities in any one stage might be reduced to a more practicable degree. The effect of compounding does not, however, reduce the stage velocities as promptly as might be at first thought, for the reason that the velocity varies as the square root of the energy of the steam. Thus, if the simple impact turbine were constructed with two stages instead of one, the stage velocity would be reduced from 4012 feet per second to 2835 feet per second, assuming a range of pressure from 165 pounds to one pound absolute. If it were constructed in four stages, the velocity would become 2050 feet per second, under the supposition that the entire velocity of the jet were abstracted in each stage. In order, therefore, to reduce the steam velocities to 500 feet per second, about 64 stages would be required in the turbine.

THE CURTIS

The nearest approach to this method of compounding the simple impact element is carried out in the Curtis turbine, in which two or more stages are employed to carry out the total range of expansion from boiler to condenser. Each stage comprises a set of expanding nozzles and a wheel carrying more than one row of buckets. The peripheral speed of the wheel is kept within convenient limits, so that if only one row of buckets were employed the steam would issue from it with much residual velocity.

In order to abstract this as far as possible, a set of guides is interposed which redirects the steam leaving the first row of moving blades into a second set. The velocity of the jet is thus reduced by each reversal in the moving blades, and this process is carried out as many times as may be necessary to absorb the initial velocity of the jet. Thus the steam in each stage is alternately accelerated in the nozzle and retarded in the blades. Low shaft velocities are secured by this arrangement, but this is largely due, however, to the use of large diameters of wheel and to the fact that, generally, a very small arc of all but the last wheel is being acted upon by the nozzles at one time. This construction makes desirable a fine axial clearance.

THE ZOELLY

The idea of compounding has been applied in a slightly different manner in the Zoelly turbine, a cross section of which is shown in Figure 2. One section of the turbine—the high-pressure end—consists of several tangential impulse elements arranged in separate compartments. Each is fitted with a number of nozzles in which part of the expansion is carried out, and the velocity immediately abstracted in the buckets. In the later stages, however, a different construction is employed by reason of the increased volume of steam. The nozzles are here slotted in the wall of each compartment, and the steam flow is in the form of an annular jet, striking the bucket in the manner of the De Laval turbine. To accommodate expansion, the radial width of the nozzle parts are progressively increased to the end of the turbine. The principal feature of the Zoelly turbine lies, however, in the construction of the disc wheels to accommodate extraordinarly high peripheral speeds. The buckets consist of

metal strips about one-half the radius of the wheel in length. They are secured to a two-piece hub by projections as shown in Figure 3, and a cross section of approximately uniform strength

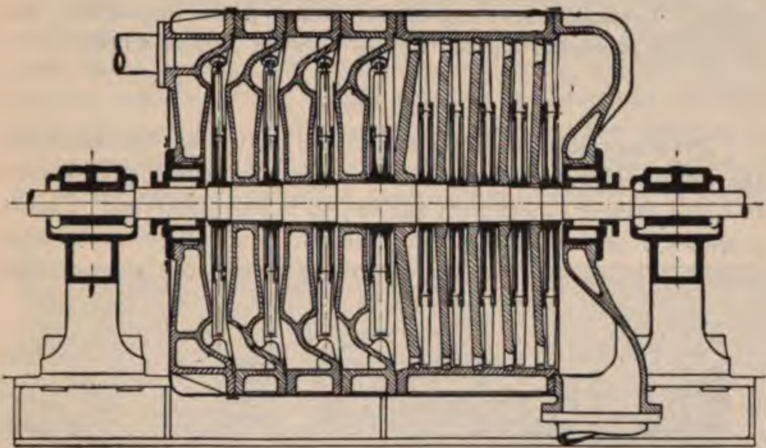


FIG. 2—THE ZOELLY TURBINE

is obtained by milling the bucket curves deeper from hub to rim. Thus the weight is largely decreased, together with the internal stresses to be provided for. Zoelly found by experi-

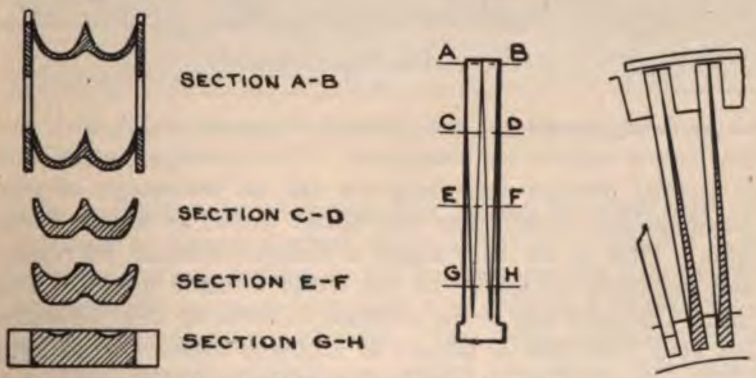


FIG. 3—DETAILS OF ZOELLY TURBINE

ments that his buckets might be spaced much farther apart than customary in the De Laval turbine without serious loss in efficiency, which justifies his construction. The peripheries of

the bucket wheels are surrounded by stationary metal shroud-wheels to prevent radial escape of the steam. The sides of the buckets are further inclosed in sheet-steel housings to reduce the windage that would occur with exposed buckets of such length. Complete reversal of the steam jet is impossible, and the action is similar to that of the familiar Pelton wheel.

THE RATEAU

Professor Rateau, in his later form of turbine, has discarded the simple impact element and employed the subdivided element to a still greater extent than any herein before described. Figure 4 shows a section of a Rateau turbine of 25 stages. Annular nozzles are provided in each division wall between stages. The

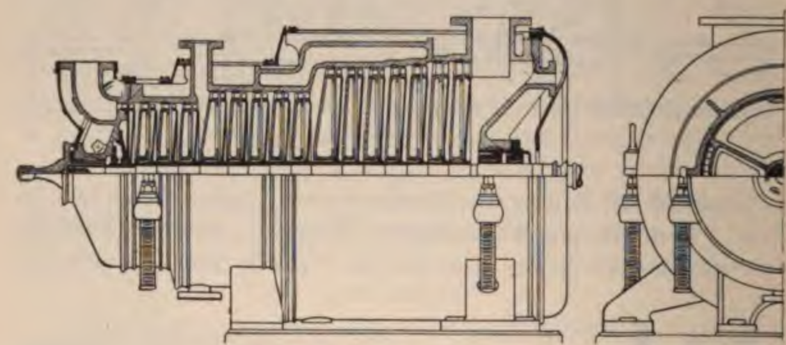


FIG. 4—THE RATEAU TURBINE

stages being numerous, the pressure drops are small, such that the nozzles require no divergence. The increasing nozzle area is secured through increasing the arc, or percentage of total circumference, rather than the nozzle width, as in the Zoelly form. Thus in the later stages a complete annular jet results, and the entire periphery of the wheel is made use of. This seems a decided step in the direction of reducing fluid velocities, but even this form is subject to frictional losses, due to large disc areas operating at high speeds in dense media.

A still further method of securing the advantages of compounding is represented in the construction of the Parsons turbine, which, however, antedates, both in conception and introduction, other forms of modern steam turbines.

THE PARSONS

In the types previously described, the original impact element has been made use of in simple or compounded form, the pressure fall being secured by nozzles and the velocity abstracted by vanes. Thus each bucket wheel presumably rotates in an atmosphere of uniform pressure at all points. Mr. Parsons, however, early conceived the idea of so designing and locating the turbine vanes that they should perform the functions of bucket and nozzle as well, at the same time confining the steam to the periphery of the wheel in order to avoid superficial friction on large disc areas. The actual construction of this type of turbine

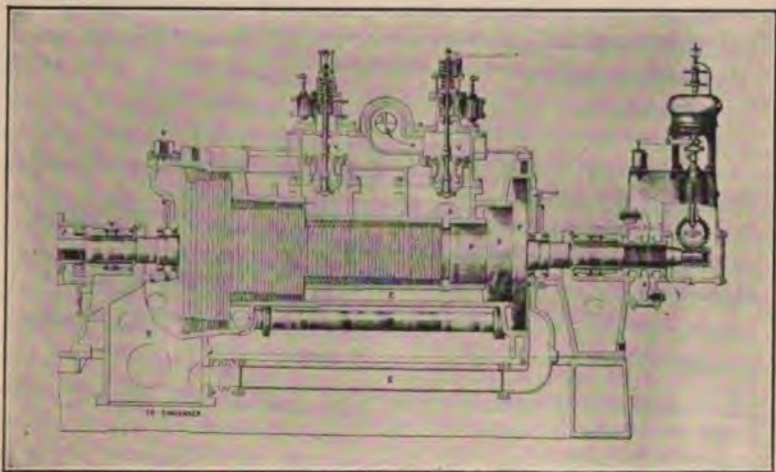


FIG. 5—A TYPICAL WESTINGHOUSE-PARSONS STEAM TURBINE

is so well known as to require only passing comment here. By reference to Figure 5, which shows a typical section of a Westinghouse-Parsons turbine, it will be seen that the steam volume progressively increases from inlet A to exhaust B in the annular space between stator and rotor. The entire expansion, which is approximately adiabatic, is carried out within this annular compartment, which essentially corresponds to a simple steam nozzle. There is this difference, however, that whereas in a nozzle the heat energy of the entering steam is expended upon itself in producing high velocities of efflux, in the Parsons tur-

bine, the total velocity, due to expansion, is subdivided in a number of steps, in each of which it is reduced through the dynamic relation of jet and vane, so that a comparatively low velocity is maintained from inlet to exhaust; this generally varying from 150 feet per second as a minimum at the high-pressure end to about 600 feet per second as a maximum at the low-pressure end. The action of the steam in this turbine differs from other types also in this respect, that the steam expands in the ring, 2, of moving blades (see Figure 6) so that a reactive effect is produced in addition to the impulse of the steam from 1. The total torque produced at the shaft from ring, 2, of moving blades is therefore due to impact of steam from 1 and reaction from 2. This process is repeated in each element of the turbine, and the average velocity may be maintained at a

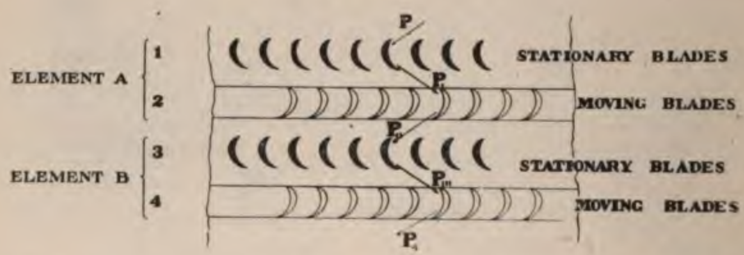


FIG. 6—DIAGRAM OF BLADES OF WESTINGHOUSE-PARSONS STEAM TURBINE

uniformly low figure throughout. It is evident that here frictional losses, due to high velocities of efflux, are largely reduced.

A longitudinal section of the turbine is shown in Figure 5. Steam enters at *S* through a poppet valve *V* which is controlled by the governor, passing through the various stages of the turbine to the exhaust, the steam then discharging vertically downward into the condenser.

In order to neutralize the unbalanced axial thrust resulting from the pressure of the steam upon the various drums of the turbine, balance pistons, shown at *P*, Figure 5, are used, these being equal in area to the effective areas of the various drums with which their pressures are equalized by ports or pipes *E*. Whatever the distribution of pressures within the turbine, due

to varying loads, the resultant thrust against the pistons is at all times equal and opposite to the resultant thrust against the blades, so that the rotor remains practically in equilibrium. The small alignment bearing, *T*, is employed simply to preserve proper adjustment of axial clearances between moving and stationary blades, and takes no thrust. The balance pistons revolve within their casings with a close fit but without mechanical friction, their peripheries being deeply grooved so as to interpose so devious a path for steam attempting to leak past the pistons as to render loss from this source of no great importance.

An important feature of the parallel-flow turbine is that the entire annulus between rotor and stator is entirely filled with working steam. This allows large axial clearances between moving and stationary blades to be employed without loss in efficiency; in actual practice, this is never less than one-eighth inch and in large blades is as much as one inch. In all forms of impulse turbines, separation of nozzle and vane results in surface friction of the jet, and particularly an entrainment of the surrounding atmosphere, resembling in effect the steam injector, thus increasing fluid friction.

It has been often held that unless a very high vacuum—in fact an almost uncommercial one—be provided, the economy of the turbine will suffer. This may be true in certain types in which there are idle portions of the bucket wheels rotating in dense media. In the parallel-flow turbine, however, losses from this source are not so much in evidence, by reason of the fact that the steam is confined to the annulus and the entire circumference is active in producing torque, thus reducing the proportion of friction to useful work. By reference to the accompanying table of tests, it will be found that the results from turbines operating under poor vacua are not less excellent, relatively, than those obtained with high vacua.

Although small axial clearances are unnecessary, it is, however, desirable to employ as small clearances as possible between blades and castings in order to economize the leakage of steam from stage to stage without doing work. The extent of this leakage is liable to be largely overestimated if the following point is not borne in mind; a point which in a considerable measure offsets the loss from this source. In a machine of given

size, the radial clearances between the ends of blades and the walls of the turbine would presumably be constant. The greater leakage would, therefore, naturally occur at the high-pressure end of the turbine or at the beginning of the expansion. By the time the lower stages of the turbine have been reached, the total volume of the steam has become so great, compared with the clearance area, that the latter becomes unimportant. All leakage steam returns energy to the working steam in the form of heat, as its action is similar to wire drawing in a restricted passage; hence it is superheated to a slight degree and serves to partially dry the working steam, which contains considerable moisture, due to adiabatic expansion.

An interesting point in turbine work is that local temperature conditions vary but little during operation and on steady loads are absolutely constant. The reversals of temperature in a reciprocating engine cylinder have no equivalent in the turbine. Thus the temperature of rotor and stator are at all points approximately equal to that of the steam in the corresponding expansion stages. Generally the stator is made of cast iron and the rotor of steel, so that the differential expansion that must necessarily exist between them has the effect of increasing or decreasing the axial clearances between running blades at different loads. This, however, is unimportant with this type of turbine, because of the ample clearances provided. The exhaust end of the turbine is bolted to the bed-plate, while the steam end is provided with a sliding foot working between machined ways on the bed-plate, so as to permit the turbine to expand as it will. In types of turbines, however, where small axial clearances exist, this question of differential expansion is not such a simple matter.

As is well known, the blade construction of the Parsons turbine consists of numerous radial blades, which are rolled out in long strips, cut to the proper length, and caulked in position around the peripheries of the rotor and stator. This construction has sometimes been considered as constituting an element of complexity, which furthermore is not conducive to low cost. In actual practice it is found that with this construction the blades are never released, except through some special cause, and are of immense advantage in economizing the delays

due to accidents, which are now and then encountered in the most perfect mechanism.*

A turbine opened up for inspection is shown in Figure 7. By placing the shaft in a sling, the rotor can be lifted out by a crane and the entire interior examined. Such a turbine can be taken apart and completely reassembled inside of two

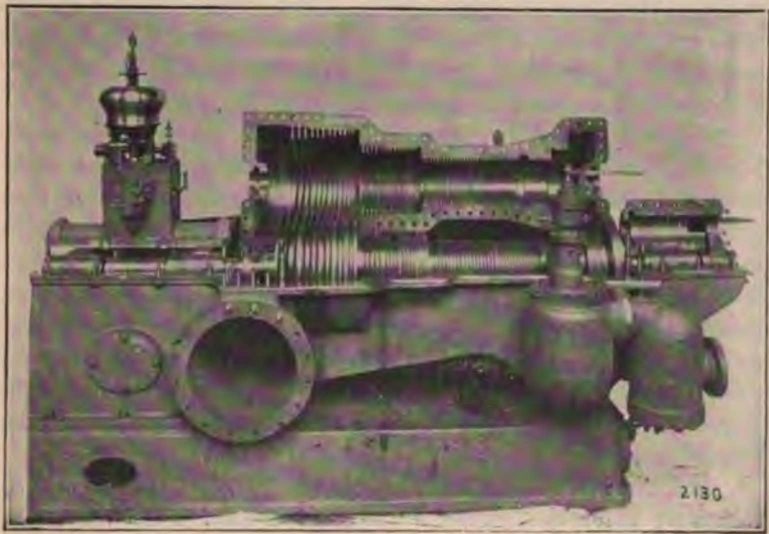


FIG. 7—400-KW WESTINGHOUSE-PARSONS STEAM TURBINE OPENED UP FOR INSPECTION

hours, which can not be said of many types of prime movers now known to us.

In any type of turbine it is necessary to provide glands at the end of the casings to prevent the escape of steam or the influx of air into the turbine at the point of entry of the shaft.

*Such accidents are, however, of rare occurrence, and one that may be attributed to the blading construction has yet to happen. On one occasion, an expanding exhaust pipe that had been too firmly anchored at the lower end occasioned sufficient distortion of the turbine casing to destroy several rows of blades. The turbine was immediately shut down, the casing opened and the débris moved away. It was then again put under steam and continued in full-load service during the day without further trouble or apparent effect on its capacity. At night, after extra blading had arrived from the factory, the machine was again opened and the damaged rows replaced. The repairs were carried out during several nights, but the turbine was kept operating every day. The accident kept the turbine out of service for about three hours.

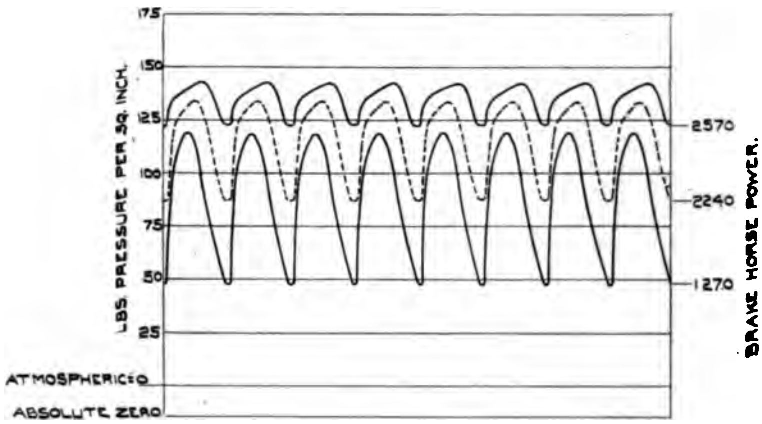
Air leakage is particularly detrimental in cases where it is desirable to maintain high vacuum. Various forms of packing glands have been used, but the later type Westinghouse-Parsons turbines are fitted with an arrangement of water-sealed glands. They require no lubrication and it is impossible for any oil to escape from the bearings or the lubrication system into the steam spaces. There are no rubbing surfaces in these glands, and it is found that they do not wear out. The water used for sealing them is small in quantity, but it is not necessarily lost, as it may, in a power plant, be taken from the feed-pump delivery and returned to the feed-pump suction.

The method of governing employed in the Westinghouse-Parsons turbine consists essentially of the admission of high-pressure steam in puffs at constant periods, but with varying duration according to the load upon the machine. At light loads, the valve *V* opens for but a fraction of the period and remains closed during the greater part. As the load increases, the valve remains longer open until at slight overloads continuous full pressure is obtained in the high-pressure end of the turbine. The operations of this valve are well shown in Figure 8, which is a facsimile indicator card taken from the admission port *A*.

On the load being still further increased, an auxiliary or secondary valve, designated *Vs*, begins to open, admitting steam to a later stage in the turbine where the working steam areas are greater, thus increasing in proportion the total power of the turbine. The governor automatically controls the operation of this secondary valve in the same manner as the primary valve *V*, so that enormous overloads may be carried during emergencies with but little loss in economy. The performance of this secondary valve may be seen in Figure 9—a test upon a 400-kw turbine—where an overload was carried to 76 per cent with a steam consumption varying but slightly over eight per cent from that of maximum efficiency.

This intermittent admission of steam to the turbine does not in the least interfere with its uniformity of rotation, by reason of the short period—160 periods per minute—and the high inertia of the rotating parts. On the other hand, it is productive of considerable gain in economy at light loads by maintaining a temperature range greater than would be possible

if the steam were throttled. Further, the continual reciprocating motion transmitted from the shaft eccentric to the admission valves through the governor occasions a slight disturbance in the latter which overcomes friction of rest due to the sticking of parts, so that the sensitiveness of the governor is largely increased. As a result, the speed regulation may be kept within two per cent between friction load and full load, or one per cent either side of mean speed. Full loads or overloads may be thrown off or on without causing greater disturbance than a



INDICATOR CARDS SHOWING INITIAL PRESSURES IN A WESTINGHOUSE-PARSONS STEAM TURBINE.

FIG. 8

momentary surge of four or five per cent in speed. On the larger size turbines, the governor is supplemented by a special automatic centrifugal safety stop, mounted at the end of the shaft, which actuates, by means of high-pressure steam, an auxiliary self-closing throttle valve located in the main steam pipe supplying the turbine. The safety stop may be set at any predetermined speed, which, if attained, causes the turbine to be brought to rest. It is employed mainly as a precaution against damage due to any possible derangement of the governor mechanism.

Perhaps no detail of turbine mechanism contributes so

largely to its successful operation at the speeds encountered as the flexible bearings employed in the Parsons turbine. These bearings consist of a nest of loosely fitting concentric bronze sleeves, of sufficient clearance to permit the formation of oil films which act as cushions, thus permitting a certain amount of vibration of the shaft, but at the same time restraining such vibration within narrow limits. This construction is particularly useful when the rotor has reached its critical speed, which occurs at a time when the rotor changes from its geometric to its gravity axis. For the larger turbines, however, and, in fact, for all machines running below 1200 revolutions per minute, the flexible bearing is no longer found necessary and is replaced by a solid, split, self-aligning bearing, lined with anti-friction metal, as in the ordinary forms of low-speed machinery.

In either form of bearing, whether solid or flexible, the viscosity of oil films is depended upon to bear the entire weight of the rotating member and separate the shaft and bearing sufficient to entirely prevent metallic friction and resulting wear. The projected areas of the journals are, therefore, so proportioned that simple flushing of the journal from a small positively-driven oil pump is sufficient to supply the bearings with oil, thus eliminating entirely the use of forced lubrication, as ordinarily understood to mean oil under high pressure. The oil is applied to the bearings at the point of lowest pressure, entering through an aperture in the top and following grooves within the inner shell, by which it is distributed around the shaft. A static head of one to three feet maintained by the oil pump is sufficient to flush the bearings thoroughly. As the pump is driven from the turbine itself, liability of a shut-down from cessation of oil supply is remote.

The lubrication system is a closed system comprising, in the order of their arrangement, pump, oil, cooler, bearings and reservoir. The only normal losses are, therefore, due to evaporation. In practice, one charge of oil will last for several months without being changed, and at the end of this period it is usual to filter and return it to the turbine.

In a number of turbine plants that have been in operation for some time, the oil required to operate the turbine averages about a fourth of a gallon per kilowatt capacity per year, or, in other words, about 100 gallons for a 400-kw turbine per

year, the oil being a high-grade engine oil. As this oil costs from 25 to 50 cents per gallon, the expense of oil does not usually amount to over 7.5 to 12.5 cents a day. Even this slight expense is not all directly chargeable to the turbine, as it is common practice to use the oil that is removed from the circulating system, in auxiliaries and other low-speed machinery.

TURBINE GENERATORS

It is an interesting fact that owing to the introduction of steam turbines the general characteristics of generating apparatus have been modified to a wide extent, and in points of running speeds have returned to the practice of the first builders of electrical machinery. Owing to the restrictions placed upon the designers by reciprocating engine speeds, the dimensions and bulk of engine-type generating machinery has of late years become enormously increased; similarly, the cost of construction. With the advent of the turbine, however, speeds have been increased to such a point as to secure, in the generator construction, minimum bulk and cost consistent with strength and durability.*

The turbine generator is more easily applied to alternating-current work for the reason that commutation difficulties involved in direct-current machinery, running at high speeds, are avoided. The preferable construction, therefore, comprises rotating field and stationary armature. In present turbine generators the armature construction is not essentially different from that of the ordinary engine-type machine. In the construction of the field, however, the centrifugal stresses necessitate a construction of greater inherent strength. Recent practice embraces two designs: one of built-up form used in six or more pole fields, and the other of a solid steel casting thoroughly annealed, bored for the reception of the shaft, and slotted axially for the reception of bar or strap windings, which are insulated and confined in position by wedges, this being for two poles.

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*A pertinent comparison may be made in the two types of 5000-kw generators which will form the power equipment of the Rapid Transit subway in New York city. The engine-type generators, run at 75 r.p.m., are approximately 40 feet in diameter and weigh 980,000 pounds. The turbine generators, on the other hand, run at 750 r.p.m., are 12 feet 6 inches in diameter and weigh 234,000 pounds, the weight of journals and shaft excluded in each case. The engine-type generators have 40 poles and the turbo-generators, four, giving the same frequency—25 cycles per second.

The turbine, however, makes possible the use of a still further type of generator, which although presenting difficulties in design at ordinary engine speeds, becomes ideally suited for direct connection to the turbine, both by reason of its electrical characteristics and its inherent strength of mechanical construction. It is well known that if the ordinary squirrel-cage induction motor runs below synchronism with the system upon which it is operated, it will absorb power from that system proportionate to the slip or drop in speed. If it is run in synchronism therewith by external means, it will absorb no power; and, if run above synchronism, it will become a generator and return electric power to the system.

When running below synchronism, the greater part of the current absorbed by the motor appears as power, but a small part is consumed within the motor itself in magnetizing its rotating field. When run above synchronism, the motor, now a generator, still requires magnetizing current from the line to which it is connected. It is therefore incapable of operating by itself, and must be run in connection with other synchronous machinery capable of supplying its magnetizing current and controlling the frequency of the system.

The induction or non-synchronous generator, unfortunately, imposes a lagging current upon the supply system, but the power factor can be brought within a few per cent of unity so that the effect upon the system may be readily neutralized. Its peculiar electrical characteristics impose limitations upon its general use for power-station work, but when employed in conjunction with other synchronous apparatus, such as ordinary alternators, synchronous motors and rotary converters, it becomes peculiarly suitable for extension to a power system in which the limit of generator capacity has already been reached. With the apparatus mentioned, particularly with synchronous motors and rotary converters, a sufficient leading current may be impressed upon the system by over-exciting the fields of these machines to neutralize entirely the effects of the magnetizing currents required by the induction-motor generator, so that, in general, if existing apparatus is ample to care for existing inductive loads with reasonable margin, the induction generator can be employed to great advantage.

A feature that is particularly favorable in rendering it

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suitable for turbine driving is that, by largely reducing the number of poles, the magnetizing currents may be largely reduced. For this reason, the limitations of the induction generator occur largely in the direction of bulk rather than otherwise. As it must operate at the comparatively high speed of the turbines, it is thus possible to reduce the number of poles to a few pairs, so that the losses above mentioned are minimized and the generator becomes commercially practicable. And as the squirrel-cage construction of the rotor is peculiarly well suited for high-speed work, we are fortunate in having here one of the few cases in which the electrical and mechanical conditions governing generator and prime mover are almost exactly suited to each other. In general, the higher the speed at which the machines can be safely operated, the less the material necessary and the smaller the losses, resulting in an extraordinarily high efficiency and power factor.

For example, in a two-pole, 60-cycle, induction generator of 500 kilowatts, running at 3600 r.p.m., the power factor may be brought as high as 98 per cent or higher at full load, and the total efficiency will be far greater than that of present generating machinery.

ECONOMY

As one of the principal claims that the turbine makes is economy of steam, and consequently of fuel, a few observations may be made upon this subject. As is well known, high economy has been obtained with the turbine operating under favorable conditions, but as abstract figures of steam, heat or fuel consumption rarely convey an adequate idea of the actual merits of the prime mover in question, it is necessary to examine the conditions under which these results were obtained. The table of tests has been prepared with a view to presenting, in as concise shape as possible, the results of several hundred tests upon turbines of all sizes and under all conditions of operation, the headings being arranged with reference to these conditions. The tests were conducted in the testing department of the Westinghouse Machine Company at East Pittsburg, where every turbine put through the shops is thoroughly tested before shipment.

Columns 51 and 52 give results under moderately favorable conditions—150 pounds steam pressure, 28-inch vacuum

and 180 degrees superheat; and in columns 1 and 3 will be found tests under decidedly unfavorable conditions—125 pounds pressure, 26-inch mercury vacuum and saturated steam.

The testing department provides facilities for the accommodation of

Four turbines of small capacity up to 500 kilowatts
Four turbines of 2000-kw capacity
*Two turbines of 5000-kw capacity

This is somewhat of a radical departure in manufacturing methods and is entirely unprecedented. At present, it is unusual practice among generator builders to determine efficiency in large machinery by other than the motor-generator method, and in the largest sizes, such as the 5000-kw Manhattan generators, the machines are not even turned over in the factory; similarly, engines above 500 to 1000-hp are seldom tested in the shop, and larger sizes are shipped without having steam turned into them. It is thus of peculiar interest that the largest turbine units will be tested under steam at the shops. The testing equipment comprises boiler plant, a gas-fired superheater and four independent surface condensing outfits, ranging in size from 1600 square feet up to 10,000 square feet surface.

The condensers, with the exception of the smallest, are all of the "counter-current" type, exhaust steam being admitted from beneath. The condensed water is received in a hot well located below the condensers, and the air is withdrawn from the top by two-stage dry vacuum pumps. These are capable of maintaining a vacuum within half an inch of the barometer with a closed suction. The vacuum with the condenser in operation depends, of course, upon the temperature condition within the condenser.

Tests are made by means of brakes or by electric generators as desired. For the latter, large water rheostats are available. For the former, a special form of water friction brake has been devised, which has proven extremely flexible in its application, and of great value.

Steam consumption is determined by weighing condensation in the usual manner. Vacuum readings are all reduced to a basis of 30-inch of mercury, necessitated by the elevation of Pittsburg.

* The latter foundations at this time are not yet complete.

The tests shown in columns 38 to 43 of the table are plotted in Figure 9. This curve embodies the results of the introduction of the secondary governor valve, and shows a remarkable range of load with high economy.

Some brake tests of a 1250-kw turbine are shown plotted in Figure 10, with vacua ranging from 25 inches to 28 inches.

Figure 11 and columns 93 to 100 show some electrical tests of a similar machine, having been verified by Mr. Julian Kennedy, consulting engineer, of Pittsburg.

Figure 12 shows the plotted results of tests carried out at

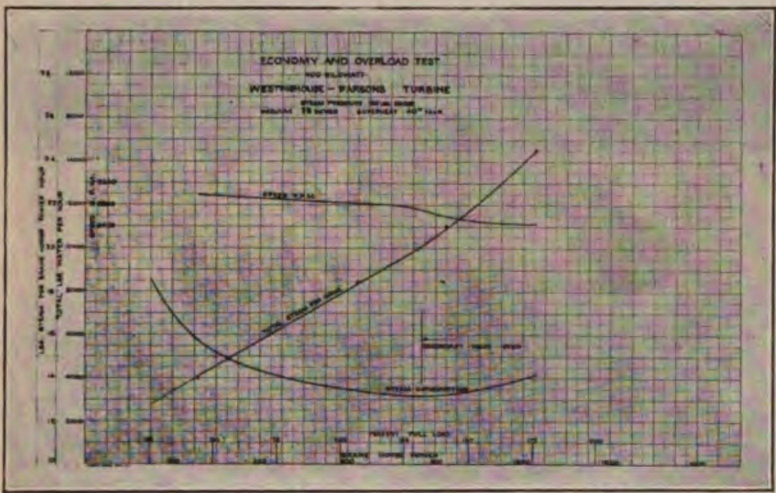


FIG. 9

the Westinghouse Machine Company's works by Mr. F. W. Dean, of the firm of Dean and Main, and shows a very good performance for a small machine.

The general appearance of these curves might possibly give the impression of a poor economy at lighter loads, especially to engineers who have been accustomed to considering engine performance on a basis of indicated horse-power. When they consider such performance on a basis of brake or electrical horse-power, they readily make a mental correction between brake or electrical horse-power and indicated horse-power

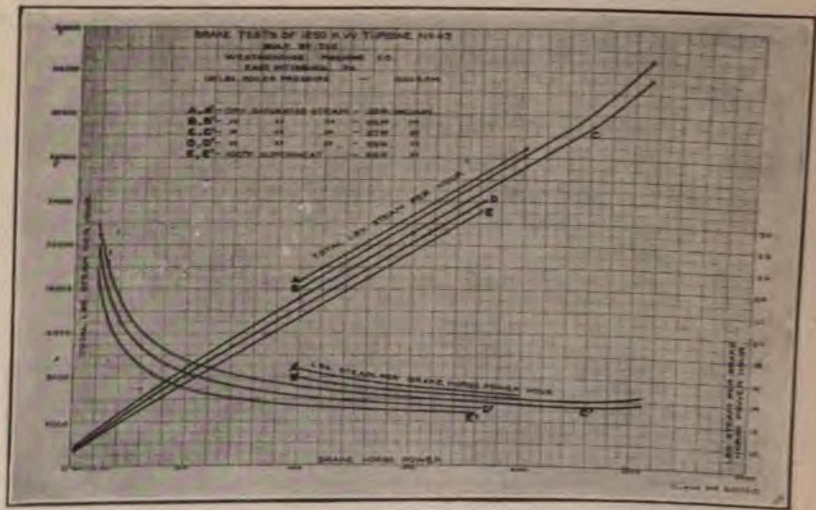

TOTAL LBS. STEAM PER HOUR
C
D
E
BRAKE HORSE POWER

FIG. 10

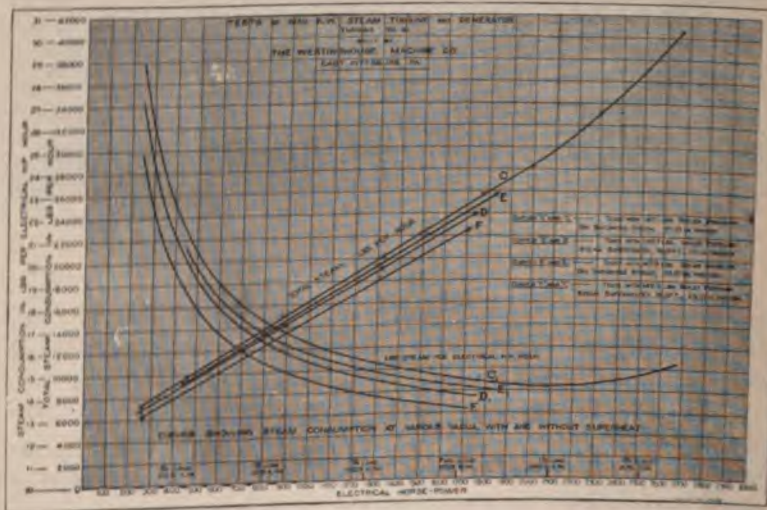

STEAM TURBINE
C
E
D
F
ELECTRICAL HORSE-POWER

FIG. 11

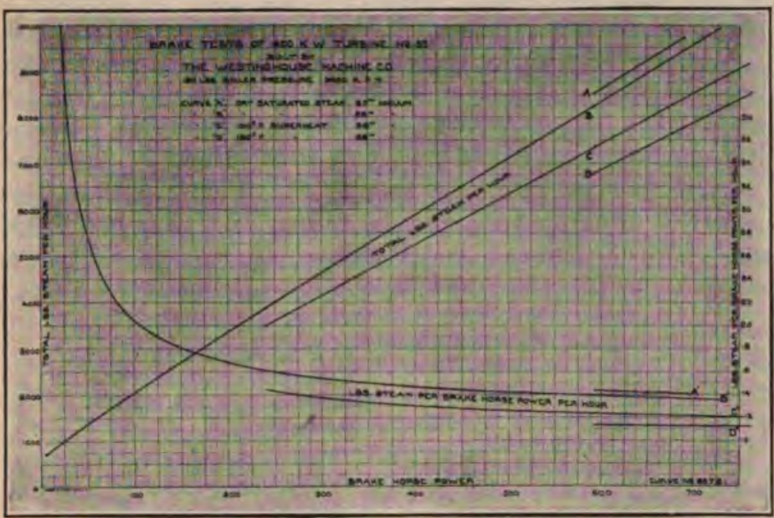

THE WESTINGHOUSE MACHINE CO.
BRAKE HORSE POWER
TOTAL LBS. STEAM PER HOUR
LBS. STEAM PER BRAKE HORSE POWER PER HOUR

FIG. 12

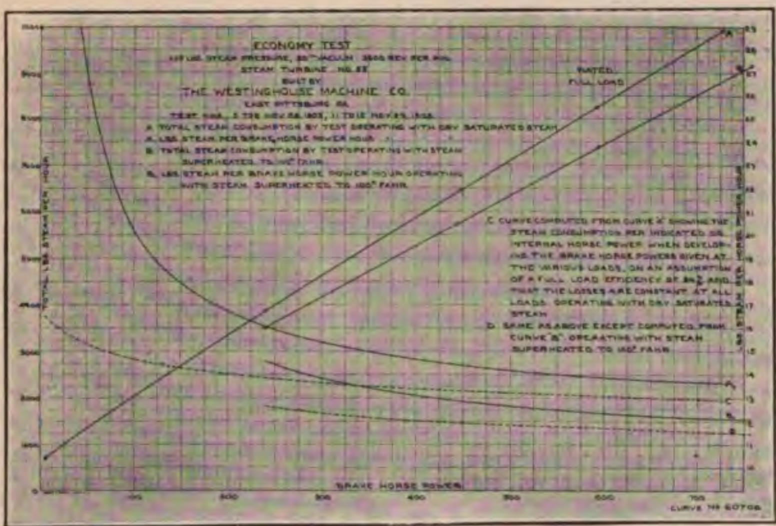

ECONOMY TEST
BUILT BY
THE WESTINGHOUSE MACHINE CO.
RATED
FULL LOAD
BRAKE HORSE POWER

FIG. 13

at full load, but seldom realize the fact that the mechanical efficiency is much poorer at fractional loads than at full loads.

It may be said that the mechanical losses of an engine are approximately constant at all loads, and assuming this, an engine that has 94 per cent mechanical efficiency at full load has an efficiency of but 88.6 per cent at half load, and at quarter load of 79.8 per cent. To exhibit this, Figure 13 has been prepared with the tests already shown in Figure 13 plotted again with the curves *C* and *D* added. The method of plotting curves *C* and *D* has been as follows. Take, for instance, curve *C*:

From tests, brake horse-power at rated full load, 593.17

Internal horse-power $= \dfrac{593.17}{.94} = 631.03$

Loss, horse-power, 37.86

This loss has been assumed constant at all loads.

Total steam, pounds per hour, 8249

Pounds steam per hp-hour, $\dfrac{8249}{631.03} = 13.08$

Pounds steam per hp-hour, when doing,

say, 300 brake horse-power, $= \dfrac{4610}{300 + 37.86} = 13.66$

In this way, curves *C* and *D* show an indicated horse-power performance at light loads that is particularly good.

In columns 122, 123 and 124 are shown some tests on a 2600-kw turbine tested under high operating conditions. The turbine, however, is of the Parsons type, and was built by Brown-Boveri and Company for the municipal electric power station for Frankfurt-on-Main.

From these curves and table of tests may be gleaned a number of interesting facts which it may be worth while to point out here.

First—The Willans line or curve of total water consumption is approximately a straight line at all points up to the opening of the secondary governor valve on heavy overloads. This relation has an immediate thermodynamic meaning and points to the utilization of steam in the turbine with the same internal efficiency at all loads; or, in other words, that the losses in the turbine from all causes, thermal, thermodynamic and mechanical, are approximately constant at all loads.

Second—The necessity of high vacua and high superheat is not essential to high economy, as has been before alluded to. This is shown in tests of a 400-kw turbine under 26-inch vacuum, 125 pounds pressure and saturated steam. A water rate of 15.41 pounds per brake horse-power was obtained, which, although not remarkable, would seem to bear out the supposition of small fluid frictional losses within the turbine. Another result of 14.4 pounds steam per b.hp-hour obtained with a 1250-kw turbine operating with 150 pounds boiler pressure and 25-inch vacuum is of interest.

Third—The gradual improvement in economy with an improvement in operating conditions is well brought out by the tests on the 1250-kw turbine. (See Figures 11 and 12.) By increasing the vacuum from 27 inches to 28 inches and the temperature of the steam from that corresponding to dry saturation to 77 degrees Fahrenheit superheat, the full-load steam consumption was reduced from 14.6 pounds to 13.2 pounds per e.hp-hour.

FOUNDATIONS AND POWER-PLANT DESIGNS

With steam turbines, practically no foundations are necessary, merely something that will uphold the dead weight of the machine. Foundation bolts are never used except on shipboard. Operation of turbines on light flooring is entirely satisfactory, thus permitting their being placed on upper floors of buildings. This also permits of the condensing plant being located immediately below the turbine. By this means the total plant occupying the minimum amount of floor space.

This is the construction made use of in the power-station of the Cleveland and South-Western Traction Company, Elyria, Ohio, and in the new power-house of the Westinghouse Electric and Manufacturing Company, East Pittsburg, Pennsylvania.

Some typical condenser arrangements have been prepared embodying the above principles. Figures 14 and 15 show a turbine-room containing four 400-kw turbines, all exhausting into a central surface condenser of 7000 square feet cooling surface; the condenser equipment consisting of a dry vacuum pump, circulating pump and condensed water pump and is suitable for maintaining 28-inch vacuum. Allowing ample space for passageways, etc., the engine-room covers a space of 35 feet

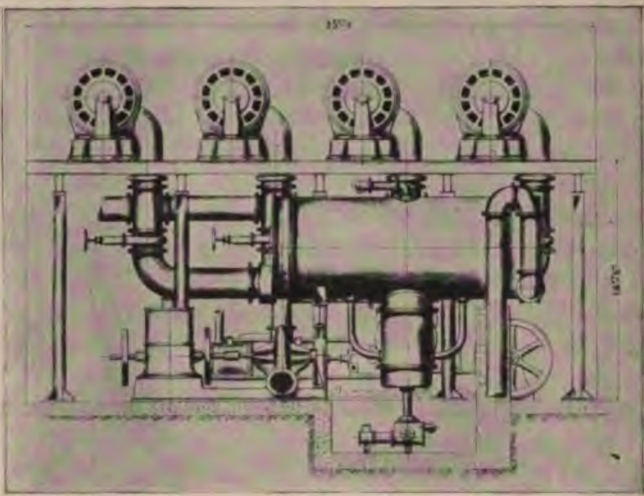


FIG. 14—POWER-HOUSE CONTAINING FOUR 400-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. END ELEVATION

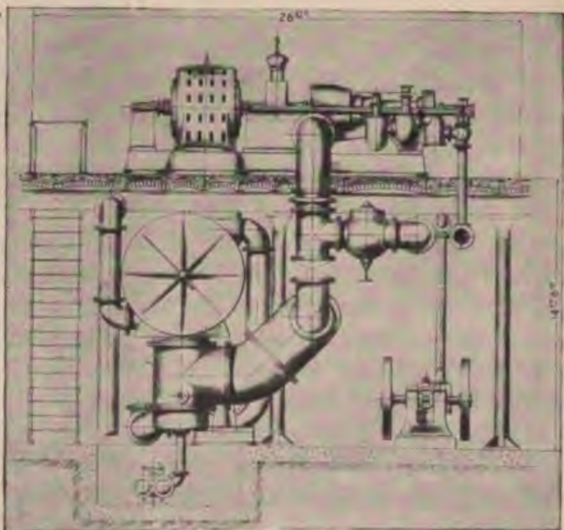


FIG. 15—POWER-HOUSE CONTAINING FOUR 400-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. SIDE ELEVATION

by 26 feet. The basement is 14.6 feet deep. The turbines are placed at 7-foot 10-inch centres.

A similar arrangement shown in Figures 16 and 17 embraces four 1000-kw turbine generators. In this case the condenser equipment consists of a surface condenser of 4000 square feet surface, a circulating pump, and a condensed water pump for each turbine. Two air pumps are shown, either of which is large enough to take care of the whole plant. In this case the engine-room occupies a space of 59 feet by 36 feet, the basement being 18 feet deep, and the turbines are placed at 13-foot centres.

A large turbine-room is similarly shown in Figures 18 and 19, consisting of four 5500-kw turbines. Here each turbine is equipped with a complete and independent condensing outfit; the condensers each having 2000 square feet surface. The turbine-room is 100 feet by 61 feet, with a basement 23 feet deep; and the turbines are placed at 22-foot 6-inch centres.

Tabulating the above figures, we have:

Number of Units	Normal Capacity of Each Unit, Kilowatts	Normal Capacity of Engine-room, Kilowatts	Square-foot Area of Engine-room	Kilowatt Capacity per Square Foot of Engine-room	Square Foot of Engine-room per Electrical Horse-power
4	400	1,600	910	1.76	.424
4	1,000	4,000	2,124	1.88	.396
4	5,500	22,000	6,100	3.60	.207

It will be observed that means are provided in all these cases for operating any one of the turbines non-condensing.

In all of these layouts, surface condensers have been shown, because it is presumable that surface condensers will be more frequently employed in connection with turbines than other types, if only because of the advantages of absolutely clean feed water and consequently lessened boiler depreciation.

It is claimed by condenser builders that with modern dry vacuum pumps, and a closed hot-well system, a better vacuum can much more easily be obtained than with a jet condenser, due to the fact that the feed water does not become aerated.

The cost of operating a surface condenser can, under favorable conditions, be kept very small, especially when the circu-

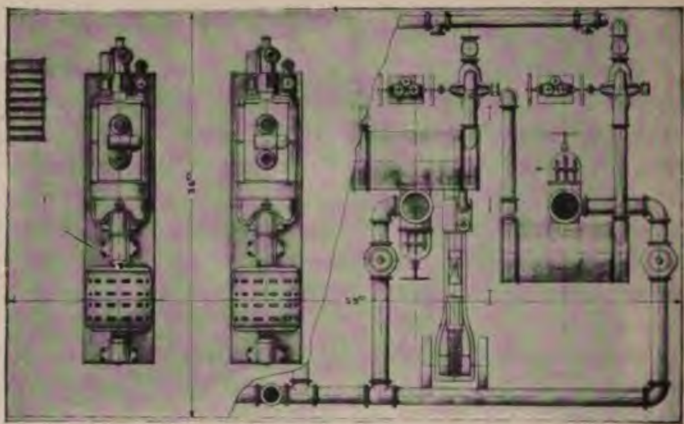


FIG. 16—POWER-HOUSE CONTAINING FOUR 1000-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. PLAN

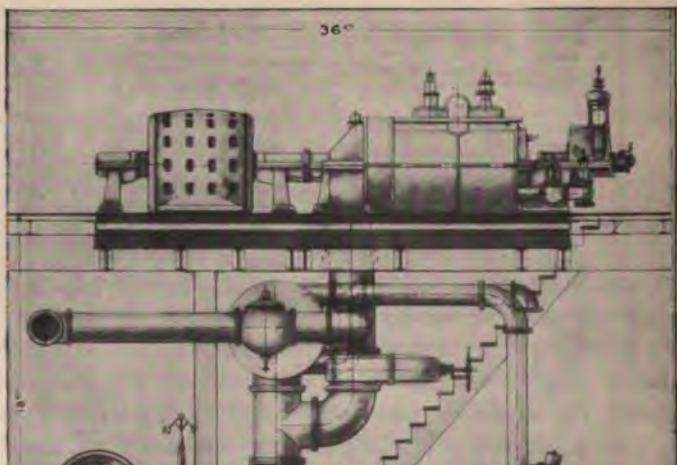


FIG. 17—POWER-HOUSE CONTAINING FOUR 1000-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. SIDE ELEVATION

lating water does not have to be raised to any height. A jet condenser, on the other hand, has to do work in order to expel

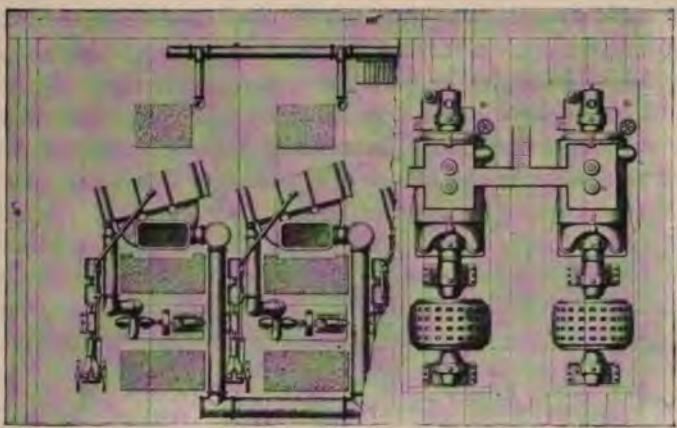


FIG. 18—POWER-HOUSE CONTAINING FOUR 5500-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. PLAN

the cooling water against nearly an atmospheric pressure, according to the vacuum. But it is a considerably simpler piece

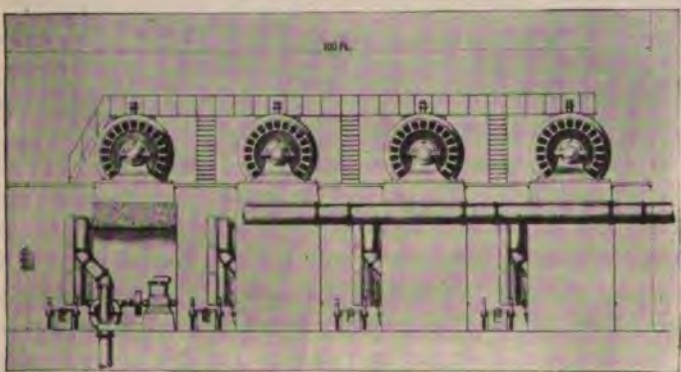


FIG. 19—POWER-HOUSE CONTAINING FOUR 5500-KW WESTINGHOUSE-PARSONS STEAM TURBINES AND CONDENSERS. SIDE ELEVATION

of apparatus, it is less costly, and is generally not subject to electrolytic troubles that are sometimes incidental to surface condensers.

Barometric condensers make a very suitable type of condenser for large vertical engines, especially when the steam can get direct to the condenser without having to be carried upward. With turbines operating with this type of condenser, the author has observed that some work is required to carry the water in the exhaust steam to the top of the condenser.

In one instance this was carefully observed in connection with a 1500-kw turbine. The exhaust left the turbine cylinder at the bottom, by means of two elbows and about six feet of horizontal pipe, passing up a vertical pipe to the condenser. Except on fairly heavy loads, the horizontal pipe had water in it, observed by a gauge. The amount of this water may be said to have been a measure of the load. The back pressure due to this piece of pipe and two elbows together with the water lying in the bottom, amounted to three-eighths inch of mercury with steady load. If the load became less, the back pressure would disappear until more water collected in the pipe and the same three-eighths-inch back pressure would be re-established. If, on the other hand, the load increased, this back pressure would rise sometimes to as high as one-inch until the water could be carried away, when it would fall back again to about the same three-eighths inch.

As turbines can expand down to the utmost limits of exhaust pressure—it is desirable to give the turbine every advantage in this respect—it is well to avoid carrying the exhaust up-hill, but give the water that must necessarily exist in the exhaust an opportunity to drain away and keep the exhaust pipe free.

While the author has endeavored to point out that high vacua are not necessary to the successful operation of steam turbines, the higher economy obtained with high vacuum warrants the condenser problem being carefully considered. It will be seen by the table of tests that each inch of vacuum above 26 inches will benefit the economy from three to four per cent.

Assume, for example, a 1500-kw turbine being operated at full load for a day at 28-inch vacuum instead of 26-inch vacuum, it will save approximately one pound of steam per horsepower per hour, or 48,000 pounds per day of 24 hours.

If we assume, further, an evaporation of seven pounds of water per pound of slack coal costing $1.00 per ton, the saving per day will amount to 6875 pounds of coal, or $3.43—equiva-

lent to $1030 per year of 300 days. The difference in cost between the two condenser equipments being about $4000, the saving realized represents an interest rate of over 25 per cent on the increased investment. With coal at $4.00 per ton and an evaporation of 8.5 pounds, the saving per year would amount to $3388, representing an interest rate of 85 per cent.

These figures will, of course, be considerably modified by fixed charges and by the fact that a power-plant usually operates for a part of the time at fractional loads, under which the

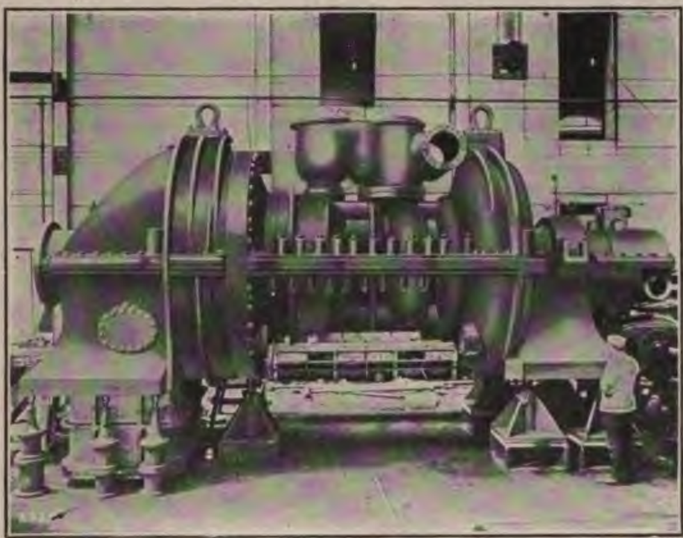


FIG. 20—5500-KW WESTINGHOUSE-PARSONS STEAM TURBINE IN COURSE OF CONSTRUCTION

economy will naturally be lower. A point, however, that should not be lost sight of is that the higher vacuum gives a greater percentage gain in economy at fractional loads than at full loads. In any event, it is apparent that it is worth while to employ high-class condensing machinery.

With air leaks eliminated and a closed hot-well system, the air pump should take no more power because of high vacuum. A dry-air pump will obviously be doing no work beyond its own friction when there is no vacuum in the condenser. Similarly,

it will be doing no work when there is a perfect vacuum in the condenser and supposing there are no air leaks. It may be interesting, as a matter of record, that the maximum load when the air pump is started comes on when the vacuum is about 20 to 21 inches.

With the circulating-water pump, however, the matter is different, as it will have approximately two or three times as much water to handle according to its inlet temperature with

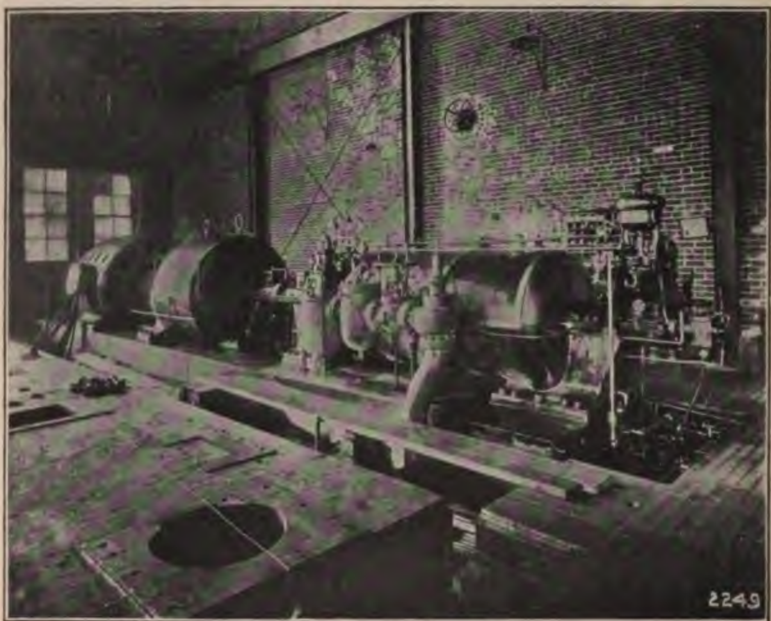


FIG. 21—WESTINGHOUSE-PARSONS STEAM TURBINES IN CLEVELAND AND SOUTHWESTERN TRACTION COMPANY'S POWER-HOUSE AT ELYRIA, OHIO

the higher vacuum. The power required to do this varies in individual cases, but it often happens that the water can be returned to the same level from which it has been taken, so that the circulating-water system forms a syphon and the pump has only the fluid friction of the pipes and condenser tubes to overcome.

Figure 20 shows a 5500-kw turbine, similar to those referred to above, in course of construction. Its overall dimensions,

including generator, are 47 feet 3 inches by 16 feet by 14 feet. Maximum overload capacity, 13,000 horse-power. On this basis, we have over 17 horse-power to a square foot, including the generator. The speed will be 750 r.p.m.

In closing, it may be appropriate to make passing comment on a few typical turbine installations now in operation. Figure 21 shows the turbine installation at the Cleveland and South-Western Traction Company's power-house at Elyria, Ohio. This machine has been successfully in operation since early in November, 1903, at times carrying the whole load of the station,

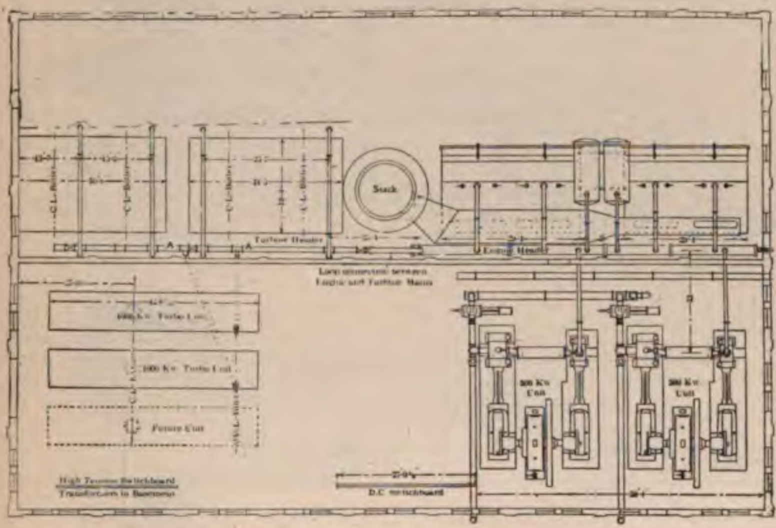


FIG. 22—ENGINE-ROOM PLAN, CLEVELAND AND SOUTH-WESTERN TRACTION COMPANY, ELYRIA, OHIO

amounting to 1600 or 1700 kilowatts, during the disablement of reciprocating engines.

A plan of the power-house, Figure 22, shows the relative amount of room occupied by the turbines and reciprocating engines. The condensers and foundations are shown in Figure 23, the condensers being placed immediately below the turbines, and the outer edges of the turbine bed-plate being supported on narrow concrete walls.

Figure 24 shows the power plant of the West Penn Rail-

way and Lighting Company at Connellsville, where three 1000-kw units are now in operation. Reciprocating-engine units of similar capacity are shown in the background. A plan of this station is shown in Figure 25. Here, again, the space occupied by the turbines, in comparison with reciprocating engines of similar power, is exemplified.

An 800-kw turbine plant, installed at the Yale and Towne

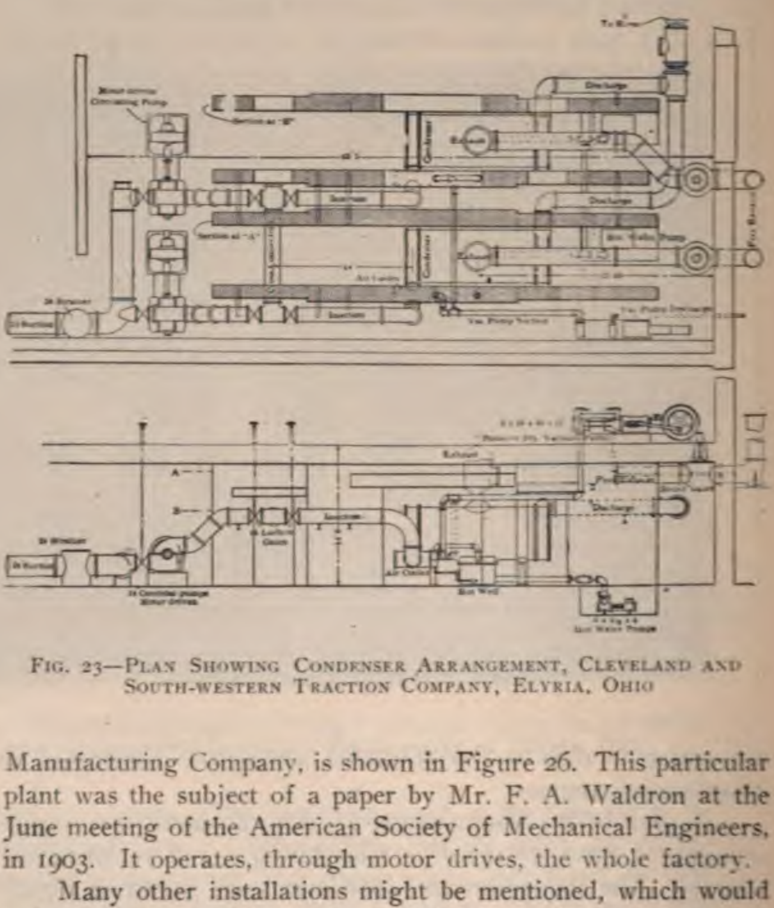


FIG. 23—PLAN SHOWING CONDENSER ARRANGEMENT, CLEVELAND AND SOUTH-WESTERN TRACTION COMPANY, ELYRIA, OHIO

Manufacturing Company, is shown in Figure 26. This particular plant was the subject of a paper by Mr. F. A. Waldron at the June meeting of the American Society of Mechanical Engineers, in 1903. It operates, through motor drives, the whole factory.

Many other installations might be mentioned, which would only serve to exemplify further such features of the steam turbine as have already formed the basis of this paper.

Suffice it to say that, at present, 43 turbines of the Westinghouse-Parsons type are in operation or under erection in

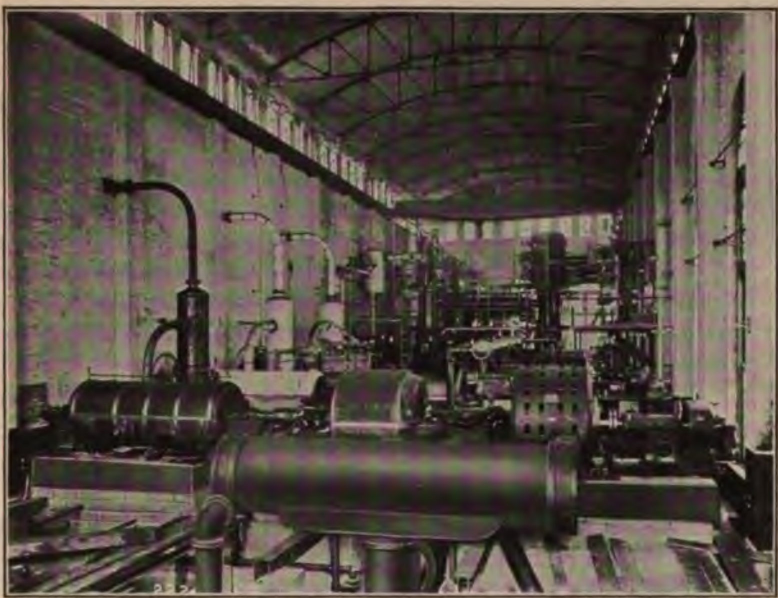


FIG. 24—WESTINGHOUSE-PARSONS STEAM TURBINE, WEST PENN RAILWAY AND LIGHTING COMPANY'S POWER PLANT, CONNELLSVILLE, PENNSYLVANIA

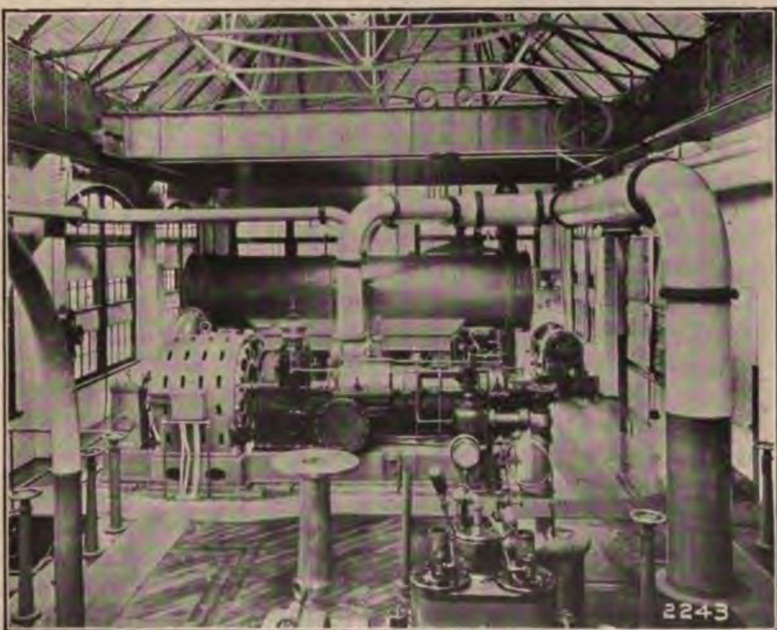


FIG. 26—WESTINGHOUSE-PARSONS STEAM TURBINE INSTALLATION AT THE YALE AND TOWNE MANUFACTURING COMPANY'S PLANT, STAMFORD, CONNECTICUT

this country, ranging in size from 400-kw to 2000-kw. These aggregate 27,000 kilowatts in capacity.

At this time there are, further, 69,400 kilowatts in turbines under construction at East Pittsburg, in all sizes up to 5500 kilowatts.

Including machines in course of construction, the present extent of turbine business for one builder represents a total of 111 machines, aggregating 96,400 kilowatts, or an average of 868 kilowatts per unit.

This record speaks for itself and would seem to evidence the complete and permanent establishment of the turbine in general power work.

THE PRESIDENT: Before having the discussion on the steam-turbine papers, I am going to call for the next report of the programme, that of the committee on award of the Doherty gold medal, Dr. Schuyler Skaats Wheeler, of Ampere, New Jersey, being chairman. As you all know, past-President Doherty, when he was president two years ago, suggested in his presidential address that he would be glad to offer a gold medal for the best paper on underground construction. This offer was accepted by the association, and it was intended to have the paper last year. Various delays occurred, and the matter remained open until I came into the presidency. During the winter we issued circulars announcing that the matter was open for competition, not only to our own members, but to the public at large. A number of papers were presented and I appointed on the committee on award Dr. Schuyler Skaats Wheeler, who is here and will make the report, Mr. Louis A. Ferguson, past-president of the association, and Mr. Henry G. Stott, of the Manhattan Elevated Railway Company, New York. I take pleasure in introducing to you Dr. Wheeler.

REPORT OF THE COMMITTEE ON AWARD OF DOHERTY GOLD MEDAL

DR. WHEELER: Mr. President and Gentlemen—The committee took the greatest interest in reading the several papers presented on the subject of underground construction, and while there was a paper that commended itself to us in many ways, namely, the one by Mr. W. H. Blood, Jr.,—which was very good, being exceedingly well put together, in fact quite re-

markable in that respect,—yet there was another, which, on account of its great mastery of detail and covering the whole subject so completely, we decided should have the preference. I might say that this conclusion was reached independently by each member of the committee. The members of the committee had no communication with one another until after they had finished their work, and the decision was unanimous and independent on the part of each member. The author of the paper selected is Mr. W. P. Hancock, of Boston. Is Mr. Hancock present?

(Mr. Hancock stepped to the platform.)

Mr. Hancock, I can testify that you have a very complete understanding of all the details of underground construction, a subject with which I am somewhat familiar, it having been my own first work. I was much impressed with your paper, and with the ability that you possess for putting your information on paper, and I have learned a great deal from it. It gives me great pleasure to hand you the medal.

Mr. Hancock: I accept with much pleasure and appreciation the medal that has been so generously contributed by Mr. Doherty and presented by Dr. Wheeler for "the best paper on underground construction." I am, however, surprised to know that so few persons entered this competition, and especially so when I call to mind the names of a number of gentlemen who could have given us interesting papers on the subject in hand. I also wish that a greater engineering interest might exist in connection with this type of construction. I think all will admit that the underground portion of a system is an extremely important one, and, that being true, it seems to me that we should lose no opportunity to improve in this direction as well as in the lines of steam and electrical apparatus. We certainly need a reliable method by which to transmit the output, and if we do not have it the reputation of the company will suffer. We also want to install the system so that the operating and repair charges shall be as low as possible in the future, and therefore I say that this type of construction is worthy of the careful judgment of engineers, both in the selection of material and labor and in the insulation.

Mr. President, I am grateful to you and to your officers, to Mr. Doherty, and to Dr. Wheeler and the associate members of the committee, also to the members of the association, for courtesies extended in connection with this competition.

THE PRESIDENT: Gentlemen, I have known of this decision for some days, and have therefore taken occasion to have Mr. Hancock's paper printed. It is ready and will be put in the envelopes of those who leave them at the secretary's office during the noon hour.*

Mr. Hancock has had nothing to do with underground construction for some years. He graduated from that, and, as you know, he is now general operating superintendent of the Boston Edison company, and the two stations that you will see this afternoon are under his personal direction.

Before closing the subject we should like to hear a word from Mr. Doherty.

MR. DOHERTY: Mr. President and Gentlemen—I was prompted to offer this medal in order to stimulate a study of underground methods. There seemed to be a lack of harmony among the methods in the various stations doing underground work. It seemed to me that the practice was not standardized, and that unnecessary expense was incurred, and I hoped to secure the contribution of a number of papers and that a standard practice could be formulated based on these papers. If this result has been accomplished I feel very well repaid for my efforts to secure it. I thank you.

THE PRESIDENT: I do not think it is necessary for us to say that we have already thanked Mr. Doherty in a formal manner for offering this medal. We are not lacking in appreciation for what he has done. The medal was formally accepted in a vote of thanks given him two years ago.

DISCUSSION ON GAS ENGINE AND STEAM TURBINE

THE PRESIDENT: The four papers read this morning—one by Mr. Andrew on "An Economy Test of a 5500-Horse-Power, Three-Cylinder, Compound Engine and Generator"; one by Mr. Arnold on the gas engine, the report of the committee on the investigation of the steam turbine, by Mr. Eglin, and the paper entitled "Practical Notes on Steam Turbines," by Mr. Francis Hodgkinson—are open for discussion.

Some time during this morning I shall be glad to call upon Mr. Mershon to say a word upon the gas engine and upon Mr. Dunham to speak upon the gas engine and the Hartford station, as I have already asked Mr. Rice to say a word on the

* For text of Mr. Hancock's paper, see Appendix A.

turbine. The matter is open for discussion. We will take one hour in the discussion, and having disposed of the subject we will take up the question of the stoker. We are ready to hear from members on the gas engine. Mr. Mershon, will you open the discussion?

DISCUSSION

MR. RALPH D. MERSHON (New York): Mr. President and Gentlemen of the Association—This paper by Mr. Arnold interests me very much, but it surprises me more because from such data as I have been able to obtain in this country as to the prices of gas engines and their auxiliaries I have not been able to get the results that Mr. Arnold has obtained. The relative costs that Mr. Arnold has taken per kilowatt for steam and gas installations are widely different from the prices I have been able to get. He gives the price per kilowatt for steam as $100 and for gas as $125. I should say that the figure for the gas engine should not be under $150, and nearer $175, judging from quotations I have received lately from various makers. I should like very much to have Mr. Arnold separate the elements that go toward making up the costs he has taken; that is, give separate figures on the engines and the electrical equipment, with the gas generator in the one case and the steam generator in the other.

I notice that in the plant on which Mr. Arnold is figuring nothing is allowed for relay capacity. If an allowance is made for relay capacity it will mean a greater investment in each case and will, of course, show against the gas engine. I would also ask him whether or not the rated capacity of this plant is based upon the ultimate capacity of the gas engine, or very nearly so, because if it is the comparison, it seems to me, is unfair. I have found that most of the gas-engine builders rate their engines at or near the load at which the engine will lie down; whereas with the steam engine we have, in case of an emergency, considerable overload capacity. It is very clear, I think, that if, as will be the case with a good many loads, the load is subject to sudden fluctuations and swings, we must have enough capacity over the average load at which the engine is running to take care of these swings. In many cases the question of relay capacity and overload capacity will be taken care of by dividing up into a considerable number of small units. It is unfair, I think, if this method is to be adopted to

help the gas engine out, to compare such a gas-engine installation with a steam-engine installation divided up in the same way.

So far as I can see from the paper, Mr. Arnold assumes that the relative efficiencies of the gas engine and the steam engine with different load factors will be the same as the one figure he has taken. It seems to me, from what I know of gas-engine performances, that the gas engine should be figured as having less relative efficiency at the lighter loads. I should like to hear from Mr. Arnold on this subject. I should also like to hear from Mr. Arnold as to the question of relative skill required in the operation of the two plants.

As to depreciation—in these figures he has taken a percentage for depreciation, thus assuming that the depreciation in the case of two classes of prime mover will bear the same relation as their cost, which is probably correct; but I wonder if Mr. Arnold has any data, covering engines that have been in operation for a number of years, to support this. I should like to hear from him on this point also.

THE PRESIDENT: I am going to suggest that each author keep his answers until the end of the discussion, and then formulate replies to all the questions that have been asked.

MR. TRIPP: Mr. President, I should like to ask Mr. Arnold if gas engines are being operated on 24 hours' continuous loads where there is considerable fluctuation on said loads and where the engines and generators, direct-connected, are being operated in parallel; particularly on high-potential, alternating-current installations?

Referring to Table IV—doubtless it is an error of the printer, but the cost of fuel per kw-hour here is six cents for steam and three cents for gas. That is probably meant to be mills, as I take it.

MR. DOHERTY: As you probably know, if you have followed the gas-engine development at all, the serious drawback has been to secure the economical and satisfactory transformation of the heat energy of your coal into gaseous energy. We have Captain H. G. H. Tarr, of the R. D. Wood company, with us, and he has devoted considerable time to that subject. If you care to call on him he can tell you of the progress being made in this matter of the greatest obstacle to gas-engine development.

THE PRESIDENT: We shall be glad to hear from Captain Tarr.

Captain Tarr (Philadelphia): Probably the greatest obstacle that the large gas engine has met is that up to the last two years we have done practically nothing in this country toward the development of the gas producer for power purposes. Realizing this, my firm (R. D. Wood and Company) has engaged in the construction of plants to meet every requirement as to character of fuel, and has endeavored to keep pace with the gas engine in capacity, economy and reliability. We have published exhaustive books on this subject, with diagrams illustrating the different processes, which we shall be glad to send to anyone making application to us; or I will hand you a copy while you are here at the convention.

You are probably more or less familiar with the Mond by-product gas producer. This is especially applicable to the larger plants, having a consumption of coal of from 30 tons of coal per day upward. As the plant is necessarily somewhat complicated—though exceedingly simple in operation—it is more expensive than an ordinary producer plant, costing from $1500 to $1700 per ton of coal gasified in 24 hours. The net result is about $1.00 per ton in net value of by-products. You will get from a ton of coal about 70 to 85 pounds of sulphate of ammonium (depending upon the character of the coal), and this, at the present market price, is worth three cents per pound. To produce this the sulphuric acid and labor must be considered, so you may safely calculate a net result of $1.10 per ton of coal gasified. If your coal costs $2.50 per ton this deduction of $1.10 will bring the coal down to $1.40 per ton. Bear in mind that this process is applicable only to the larger plants, namely, those of 25 tons or more capacity in 24 hours. In the smaller installations the ordinary producer is used, or what has been known as the Taylor producer.

I think the general impression is that you can use only coke or anthracite coal in a non-by-product producer for power, which is entirely erroneous. For a number of years, in Germany, they have cleaned gases by a most simple process, whatever producer is used, experiencing no difficulty whatever in the reliability or the length of time that the engine can run. As an illustration, we have been for some time running our own shops on this form of producer, connected with gas engines, using bituminous coal, with most excellent results, and we are prepared to make estimates, plans and installations with sufficient guarantee on this point. The cost of producers varies, depending upon conditions, from $17 to $22 per horse-power.

The general impression that there would be trouble on account of the gumming of valves in the engines, resulting from the tar in the bituminous coal, is disproved by the fact that many engines are in operation to-day under these conditions that have not been stopped or cleaned for several months. In fact, it may be accepted that with this process the running of an engine is as reliable as with the use of anthracite coal or coke.

I thank you very much for the opportunity to explain what we are doing, as we are satisfied from the individual inquiries we are constantly receiving that this development is so recent that the majority of users of power are not informed regarding it.

MR. WILLIAM R. GARDENER (Pittsfield, Mass.): I have been very much interested in Mr. Arnold's paper. It deals with a subject I have been looking into for some months, and he has very ably given some information that I have failed to pick out from other sources. I do not claim to know anything about the subject—I am simply a learner at the feet of other gentlemen who know all about it. I have one or two questions I would ask. I would say first, however, that a few weeks ago—perhaps rashly—I made the statement that by the use of the gas engine, using producer gas, a kilowatt could be produced for one cent; and I should like Mr. Arnold to remember that and tell me how far out of the way I am—coal costing $3.50.

Mr. Arnold mentions several times in his paper a fuel that can be and is being used for this purpose. I see nothing there in regard to peat as a fuel. I understand that these swamps located all about us—all over the world in fact—are simply coal in what may be called its earliest stage; nature has worked upon it only two or three million years, and in time it will become coal. As I understand it, the fuel taken from these bogs and put through a machine and properly dried, makes a very good producer gas. I hope some of these gentlemen who are posted on the gas engine will give me some information on the value of this bog fuel, or peat fuel, for purposes of comparison.

MR. J. D. ANDREW (New York): I ask what advance has been made in the design of large sizes of vertical gas engines? In many places the floor space available makes it absolutely necessary to put in a vertical engine. It is quite possible to install gas producers that will occupy approximately the same space now taken up by boilers and steam plant, but the present

designs of gas engine require three or four times the floor space necessary for steam engines or turbines.

THE PRESIDENT: I shall be glad to call upon Mr. Rice, of the General Electric Company, to say a word on the turbine situation primarily and the other matters incidentally, if he feels so inclined.

MR. R. J. RICE (Lynn, Mass.): Mr. President and Gentlemen—The Curtis turbine consists, in its simplest form, of one or more stationary nozzles which discharge steam at high velocity into several rows of moving buckets alternately with stationary buckets, the office of which is to reverse the jets of steam and redirect them in a manner suitable for use in the next row of revolving buckets, until finally the steam is discharged from the last row of buckets and its velocity practically absorbed. By removing only a portion of the velocity from each row of buckets and by providing a succession of rows, the velocity of the wheel is proportionately reduced. We also possess in the Curtis turbine another and most effective way of keeping down the speed of the buckets. If we confine ourselves, instead of expanding our steam from boiler pressure to vacuum in one operation, to an expansion of one-half or one-quarter of this amount, we considerably reduce the losses in the nozzle, and also the velocity of the steam. In having a lower velocity we can absorb this velocity with a considerably lower bucket velocity. It is, then, simply necessary to provide two or more sets of expanding nozzles in series, each with its several rows of moving and stationary buckets, to neutralize the energy of the steam. These groups are termed "stages," and the Curtis turbine is at present built with one, two, three or four stages, depending on size, steam pressure, and whether we are expanding into the atmosphere or into the condenser. The flow of steam through a nozzle follows perfectly definite laws, and enough is known of these laws to enable us to predict with accuracy the velocity developed by nozzles of various forms. Furthermore, the flow of steam at any given pressure through a nozzle of given size can be calculated as accurately as it can be condensed and measured.

We have, therefore, means of accurately determining the weight and velocity of the steam as it strikes the buckets. If the velocities of steam used in the Curtis turbines were utilized in a single row of buckets, the speed of the bucket rows would have to be nearly one-half the velocity of the steam in order to

obtain the highest efficiency. However, by using several rows of buckets a portion of the velocity is utilized in each row, and instead of being obliged to run our wheels at a speed of 1200 feet, or even 600 feet, as in the case of some types of turbines, we can use the more conservative speeds of 250 feet per second as a minimum up to 450 as a maximum. This low bucket speed also brings along with it another very important advantage, combined as it is with the use of a very moderate number of nozzles to admit the steam to the first stage. I refer to low speed of rotation, which follows from low bucket speed and the possibility of large wheel diameters, since we are not, as in some types, obliged to admit steam around the entire circumference of our wheels.

The Curtis buckets are machined from the solid material of the bucket wheel, or from the metal of a substantial solid segment, securely fastened to the wheel rim, or cast from appropriate material in the same solid way; and the ends of the buckets are covered by metallic bands riveted to the bucket ends. While the strains in the buckets are considerably less than in other types, because of the low bucket speed in the Curtis turbine, the construction is in every way more substantial. The bucket wheels are also free to expand in the direction of their diameters, and the buckets are free from possibility of injury by coming in contact with stationary parts.

These turbines are constructed in sizes varying from 1.5 to 5000 kilowatts. Up to and including 300 kilowatts the turbines are constructed of the horizontal type. From and including 500 kilowatts upward, the shafts are vertical. The packings used between the steam and the atmosphere are sealed by steam, no oil coming in contact with the steam. The condenser steam can therefore be returned to the boiler and used over and over again without fear of deterioration of the boiler surfaces. The advantage of the vertical arrangement where the weight of the rotating element is considerable is almost self-evident. Friction and wear on the bearings are reduced almost to a minimum, and in our largest turbine it is possible to move the rotating parts by hand when the oil pressure is on the step bearing. This step bearing consists of a pair of cast-iron discs, one rotating with the shaft and attached to the bottom end thereof, the other stationary, placed vertically under the shaft and adjustable upward and downward, to adjust the position of the rotating elements. These discs are kept out of contact by

means of a film of oil, which is forced between them by a pump, sufficient pressure being exerted to lift the shaft. The shaft, therefore, rotates on a film of oil of definite thickness. The oil pressure is maintained at a uniform amount by means of an accumulator.

Regulation of speed is performed by a shaft governor of great power and sensitiveness, which actuates instantaneously through suitable apparatus a series of valves, each one of which admits or cuts off the supply of steam from one or more nozzles. These valves are always either fully opened or closed. No throttling occurs, and the nozzles therefore work at their maximum efficiency. To this fact is due the high efficiency of the Curtis turbine at variable loads. Tests under actual working conditions have shown that with a variable load the turbine maintains its efficiency, due to the fact that the nozzles are always operating under their designed conditions.

Fortunately, it is easy to obtain a high vacuum with the turbine at a very moderate increase in the cost of the condensing apparatus as compared with that necessary to obtain 26 or 27 inches, and although a high vacuum is not essential to the proper operation of the turbine, the turbine is capable of utilizing the energy contained in steam to a much greater extent than is a reciprocating engine, and the economy of the turbine is therefore increased by the increase in the vacuum. The turbine is free from air-leaks, and with a short connecting pipe between the condenser and the turbine, and a condenser of liberal size, 29-inch vacuum is being obtained in many cases. Objection has been made by some that an excessive quantity of cooling water is necessary, but such is not the case, only two and a half to three times the usual amount of water being used, and its quality is not important. Roughly speaking, it may be stated that the gain by increasing the vacuum varies with the amount of the vacuum, becoming greater as the vacuum increases; but in general it may be stated that with high vacua one inch of vacuum is equal to five or six per cent gain in economy. Other forms of condensing apparatus than surface condensers are used to some extent in connection with turbines. When the water supply is limited cooling towers may be used, and when it is ample and it is not desired to return the condensed water to the boiler, syphon condensers with dry-air pumps may be installed with good results.

Without going into details in the matter of steam consump-

tion, it may be stated that the turbine uses no more steam than do the best reciprocating engines, both tested when new and under similar test conditions. In practical work, with the load varying considerably—for instance, when the engine is driving a street railway—the efficiency of the reciprocating engine is considerably reduced. The turbine is not subject to this reduction of economy, but gives the same average economy with varying load under the most unfavorable conditions. Tests with a very variable load have shown that the average steam consumption at the average load is exactly the same as if the load had been stationary at this average amount for the same length of time. The steam engine deals with the pressure and volume of the steam; consequently the valves and pistons must be steam-tight and must always remain so. The steam turbine deals with mass and velocity and is therefore independent of tightness for its economy, and it has no packings similar to piston or valve packings. The advantage of this is that it retains its original economy as long as it is operated, while the steam engine rapidly loses efficiency, due to the wear of these parts. While, therefore, there may be equally high efficiency at the beginning of service, the turbine will ultimately be in the lead. The only possibility that may affect it unfavorably is that of deterioration of the surfaces of the nozzles and buckets. The higher the steam velocity, the greater this possibility becomes. We should therefore expect the wear in the Curtis turbine to be much less than in the De Laval, and less in the four-stage turbine than in a one or two-stage turbine. All of our large turbines are made with four stages at the present time. As a matter of fact, if such wear should take place it would be confined to parts inexpensive and readily replaceable, and turbines operating for two or more years show no sign of it. We may reasonably expect, in the long run and for service extending over a term of years, that the turbine will hold its economy better than the reciprocating engine.

As regards the advantage of the small floor space required by the turbine, a case has recently come to my notice where the conditions were unfavorable to the installation of turbines; yet in this case two engines of 500-kw capacity were all that could be installed in a certain power station, whereas five turbines of the same size could be readily located.

The valves of the Curtis turbine are always under the control of the governor, even up to an overload of 50 per cent;

the steam-consumption curve is therefore continuous and does not change its characteristics. The cost of foundations is extremely small as compared with those of reciprocating engines; in fact, very little foundation is necessary. We have some turbines of 500-kw capacity operating on the second floor of a mill and standing on floor beams.

The report of your committee shows very fairly the results of the practical application and operation of these turbines, and shows that the step bearing especially has not been a source of trouble. We have some 20 of these turbines, of various sizes, in operation and operating with excellent satisfaction.

THE PRESIDENT: We do not want to confine the discussion on turbines to the manufacturers, but should like to have the central-station men take an active part in the discussion.

MR. ABBOTT: I would ask Mr. Hodgkinson to describe the arrangement for the closed hot well, and what improvement in vacuum results from it; I should also like to know what is the real advantage, and how much it amounts to, of superheated steam. It is still something of a moot question, I understand, as to whether or not the advantages really amount to all that it costs.

MR. DOHERTY: There are a few points in connection with this discussion that I hope will not be lost sight of. I think that the present development of the gas engine and the present development of the steam turbine probably give each of them a field of its own. A few years ago I had occasion to install some large gas engines, some of the first turned out by the Westinghouse company, and I was almost universally condemned for my part in that installation. There was a pronounced prejudice against the internal-combustion engine. I believe that practically every authority on thermodynamics to-day believes that the ultimate prime mover will be the internal-combustion engine. I will let the persons interested in these engines believe that, but I do not want to go on record as believing it myself. I do not believe it will be the steam turbine, but, in my opinion, if it is a question between the steam turbine and the internal-combustion engine I think the internal-combustion engine will unquestionably be the eventual prime mover.

The characteristics of the steam turbine and of the gas engine are very different. A gas engine is very efficient so far as heat for useful work is concerned, but to get efficiency from the gas engine you will generally find that you get the best results at the absolute maximum capacity of the engine. This is princi-

pally because you have certain constant losses, which are there in the aggregate in the same quantity regardless of the load on the engine, and these losses even amount to 25 per cent of the capacity of the engine. No matter what the load on the engine may be, the losses are 25 per cent of the capacity; therefore if you have only half-load on the engine the losses become 50 per cent.

We have a gas-engine station at Madison, Wisconsin. We are now putting a steam turbine into this gas-engine station. The ability to operate steam turbines and gas engines together, and operate them economically—and perhaps more economically than either alone would permit—is a matter that I believe to be of considerable importance. Your gas engine costs much more per horse-power at the start, and your fixed charges are therefore heavier. Now, then, if you can save a certain amount on the operating cost of a gas engine you must be able to operate that engine a sufficient number of hours to make that saving in operating cost more than balance your increased fixed cost. You can not do that with a low load factor; but if you already have steam engines in I think the ideal arrangement for the use of a gas engine would be to put in an installation that would take care of a portion of your load—a portion only—and that should be the portion that operates 24 hours a day. Instead of operating your engine to give you constant potential on the machine, if you will operate so that it runs at a uniform speed and at its maximum load, and have the fluctuations of the load taken up by the present steam engines, you will secure very high economy from the gas engine. Our present steam engines, we know, are not efficient on a variable load, but a steam turbine has the characteristics of any rotary prime mover and it has some peculiar characteristics of its own; chiefly the one that each part is working at the same temperature, which enables you to get away from the bad effects of fluctuations of temperature and what would be the cylinder condensation of your steam engine. Therefore, by using gas engines running at maximum load and arranging the government so that the steam turbine will take up the fluctuation, you can work out a condition where you will get a higher efficiency than with either one alone.

In one plant with which I am connected we have a peculiar load. It is at a summer resort. We recently had occasion to consider the advisability of renewing our generating equipment.

We found there was one portion of our load that ran for 391 hours per year, and it was absolutely impossible to save the fixed cost on a new installation to supersede the present installation, even though the present installation is brutal in its consumption of fuel. It was run for such a short period of time during each year that there was no opportunity to save these fixed costs.

In another station with which I am connected it is the purpose to operate with gas engines the portion of the load that runs constantly. We shall run the plant for the present with the reciprocating steam engines, but, assuming that there is no more than normal progress made in gas engines and steam turbines, we shall put in our additional equipment in steam turbines and try to keep our steam reciprocating engines and gas engines working at a suitable load, taking all the fluctuations with the steam turbine.

A paper read before this association two years ago by Mr. Charles H. Williams makes the statement that the present gas engine is relatively no better developed now than the steam engine was during Watts' time, and I agree in that opinion. The gas engine has wonderful possibilities. The steam engine has inherent drawbacks that we have all nearly given up hope of overcoming, and the immense amount of heat contained in the exhaust will always be contained there under present conditions of operation.

In figuring the efficiency of gas engines and what you can save with them in any particular station, you must have not only the load curve for a given period of days or months, but you must have the fluctuations of the load up and down. You must always have enough gas engines to take the full swing of the load. With a steam engine you can run one or two circuits full swing if you wish to take care of fluctuations. If you have a fluctuating load you probably have a load factor on your engines not to exceed 50 or 60 per cent. In figuring what result you will get from a gas engine you must divide your consumption of heat into two parts; the part that overcomes the constant losses of your engine and the part doing useful work. A simple formula works out the consumption of heat per brake horse-power. I will give an example, but it will appear more fully elsewhere.

The question, covered by Captain Tarr, of the development of a suitable gas for gas engines is worthy of consideration by

every engineer interested in this problem. There are certain peculiar things in all gas generators; one of them is the fact that you can not get enough capacity per square foot of grate surface. The quality of the gas depends on the velocity of the oxygen through the fuel bed, and if that velocity is excessive your carbon will be found in your products as carbonic acid gas and not as carbonic oxide. In other words, your oxygen uniting with your carbon presumably forms CO^2. If you have a low velocity through the fuel bed the CO^2 will be composed from CO_2 plus C equals $2CO$, but to accomplish that decomposition requires a certain time contact between a given atom of carbon and a given molecule of CO^2. If the velocity is so high that the time contact is not sufficient, you will not make a satisfactory gas.

The matter of washing and purifying blast gases and producer gases is receiving considerable attention on the other side, but I doubt if it is receiving as aggressive attention on this side of the Atlantic as it deserves. The producer-gas furnace, I believe, would cost more for a small installation than boilers would cost and considerably less for the larger installations.

You also have greater ease in handling your fuel with a producer generator than with an ordinary boiler equipment. There is no reason why you can not handle it with industrial cars, or by some simple mechanical method, such as is used in handling coal and ashes, whereby you have no considerable investment and the equipment is easily and cheaply maintained.

There were one or two other points touched upon by the various speakers into which I think they should go more fully. One is the small space occupied by the steam turbine. In my own work I have not found that we could always avail ourselves of the lesser space required by the turbine; or, at least, could not avail ourselves of it without using a system of steam piping that would not readily appeal to good engineering practice—or what would be considered good engineering practice. We must have boilers that give us a bigger capacity per lineal foot of the boiler-room, and I am just now trying to interest one manufacturer in the building of a very deep but very narrow boiler. The present boilers will stretch out a very considerable distance in lineal feet, while the steam turbine could be put in a small space in the centre and in front of these boilers. There are two or three ways in which we have proposed to overcome

this difficulty ; one is to have our boilers in stacks, back to back, and have practically a double boiler-room with a fire-door on each side and lead the steam piping from one firing alley to the engine-room. Another plan is to build the boilers with the firing doors at right angles to the turbine and have short alley-ways running up into this group of boilers. A third way is to design a special boiler having little width and considerable depth, probably going to a vertical boiler. Another method that was suggested, but was not looked upon with favor, was to put the boiler-room on each side of the turbine-room.

The question of condensers and superheaters has been touched upon here slightly. I have never been able to satisfy myself that I can not get a higher vacuum from a jet condenser than can be secured from a surface condenser. I am sorry not to be in shape to give figures at this convention, but shall be ready to do so next year, I hope. We are going after it in a different way from that which is usually followed and we expect to get higher vacuum with the jet condenser. The question of superheaters seems to be a rather serious one. It is hard to control the degree of superheat. The superheaters burn out. No one seems to be able to give any definite figures on the heating value of a unit surface of superheater. We know pretty well what we can do with a boiler. At certain times of crowding we can put 3000, 4000 or 5000 B. T. U. per square foot through the boilers, but when we get to the superheaters the capacity per square foot diminishes considerably. The design of the superheater in question has a great deal to do with this. The relative thermal capacity between the water in your boiler and your steam would be as one is to something over 3000. Unless you have active circulation in the interior of the superheater you have a condition of transferring heat from one gas to another through a metal diaphragm, and, while the metal diaphragm interposes but little resistance, as soon as the first layer of gas on each side has taken the same temperature then you must transfer your heat virtually through a non-conductor of unknown thickness, a metal diaphragm of low resistance and then another layer of gas that is almost a perfect non-conductor. Therefore, active circulation of your combustion products on one side and active circulation of the superheated steam on the other side must be the solution of high capacity per unit of surface of a superheater.

The President: I will ask Mr. Arnold to make reply to

the various questions that have been asked, as he is the only person who has been asked any questions in connection with this discussion.

MR. ARNOLD: Replying to Mr. Mershon's remarks in regard to the relay capacity and rating of the engines, it must be borne in mind that we took into consideration a lighting plant rated at 2000-kw capacity with a 20-per-cent load factor. A gas engine is ordinarily rated on its brake horse-power at about 15 to 20 per cent under its maximum capacity, while steam engines are rated at their most economical cut-off on indicated horse-power, and have, say, 50 per cent overload on that rating.

The difference between indicated and brake horse-power amounts to considerable, and the operating capacities of the two engines approach more closely than would ordinarily be supposed. Considering the fact that this is a lighting station and has an ordinary 20-per-cent load factor, the relay capacity is well taken care of by the way in which the units are laid out.

Any combination of gas-engine units or any combination of steam-engine units may be taken to suit the load curve, and the engines blocked in in the manner that will best take care of it. In this connection it will be well to remember that very small gas-engine units may be run with approximately the same efficiency as large gas-engine units, and even the small gas-engine units are notably more efficient throughout their range of load than is the steam engine. Another point that comes right in here is the relative efficiency of the gas engine, which is spoken of as having a lower *relative* efficiency at light loads. I think that while its efficiency *does* decrease at light loads, as does that of the steam engine, by reference to the curves of kinetic efficiency of the engine—Figure 11—you will find that at half load the brake or kinetic efficiency of the engine—that is, heat input to the heat equivalent of the work done—is 21 per cent. Of course, below half load the curve has more of a tendency downward until it gets to zero; but that engine—175-hp rated capacity—when it is putting out only 26 brake horse-power, has a kinetic efficiency of over 10 per cent, and on its rated capacity and upward, over 26 per cent.

With regard to the relative skill required to operate the different engines, and the amount of attendance necessary, Mr. Doherty has touched upon the fact that the large stations can be taken care of with much less attendance, also with less

relative skill, than is required in the boiler equipment of a small plant. It has been our experience that the engineering skill, the number of operating engineers, and the general attendance upon the equipment of either gas or steam engines of the same size and importance of plant, are about equal.

I should like very much to give Mr. Mershon the figures in connection with the cost of the equipment, but it is an item that would obviously require a great deal of time to bring about in detail, and realizing that there are other speakers who would like to have time in which to address the convention I will ask to be excused from a further reply to this question, except to state that the figures given were very carefully and conscientiously determined.

As to the matter of depreciation of the gas engine, we, of course, have not had so much experience with the depreciation of gas-engine machinery as we have had with steam-engine machinery, but all the experience we have had points to the fact that the gas engine quite holds its own with the steam engine, so far as the ultimate life of the machinery is concerned. Owing to the high pressures dealt with and some of the more intricate valve mechanism employed, it will perhaps be found to cost slightly more per horse-power for repairs than will ordinary steam-engine equipment; but I do not think it will do so when compared with the more intricate designs of the higher types of multiple-cylinder, releasing-gear steam engines, using superheated steam and other refinements that go to make up an engine of highest economy.

I should like to state a figure for repairs that I have in mind for a gas-engine lighting station of 800-hp rated capacity, in five units, doing 24 hours' service, the complete repairs for which for the year 1903, including repointing of igniters and everything connected with the gas engines, was $102, or something less than 13 cents per horse-power per year.

In reply to Mr. Tripp, as to the plants operating in parallel, I will say that with perhaps one exception all the plants referred to in the paper, and also those shown on the screen, used to drive alternating-current generators are operating in parallel, and there are other instances that might be cited.

With regard to the 24-hour service, a number of the plants referred to and illustrated are giving 24-hour service, and I might mention the Rankin plant, of the McClintic-Marshall Construction Company, Pittsburg.

There is another plant to which I wish to call your attention as giving good service, it being quite a good-sized plant; it is that of the Iola Portland Cement Company, Iola, Kansas, with 3000 horse-power of engines, operating crushing and grinding machinery 24 hours a day. The plant has been in operation about four years.

With regard to Mr. Gardener's statement that by the use of the gas engine, using producer gas, a kw-hour could be produced for two mills, I would say that this is correct, provided of course Mr. Gardener means only the fuel expense, and does not pay over $2.00 per ton for coal.

Under the assumptions taken in the comparison made in the present paper, the fuel expense per kw-hour is three mills, but this is due to assuming $3.00 as the price per ton of fuel.

The vertical double-acting gas engine has not been developed and put into service so extensively as the horizontal gas engine, but several have been made by the Westinghouse companies from 500 to 1500 horse-power. These are all in operation in Europe.

THE PRESIDENT: It has been suggested that Mr. Alberger might be able to answer Mr. Abbott's question on the subject of the hot well.

MR. LOUIS R. ALBERGER (New York): I suppose Mr. Abbott referred to the closed hot well in connection with dry-vacuum systems, in which the water is collected in a closed hot well and pumped out into the atmosphere and the air removed by a dry-vacuum pump.

MR. ABBOTT: Is the air kept from coming in contact with the condensation—absolutely from contact with the condensation?

MR. ALBERGER: There are various ways of accomplishing the separation. One is to keep all air entirely away from the water, and one is to separate it after it comes in contact with the water; there are two ways.

MR. ABBOTT: What I had in mind was with reference to Mr. Hodgkinson's remark on the advantages of a closed hot well. I also had in mind an installation where the water is not kept absolutely from the air, and I was wondering if there was a possible increase in efficiency by keeping it absolutely from contact with the air. The former is the dry-vacuum and the latter the wet-vacuum system.

Mr. Alberger: You mean keeping the water from contact with the atmospheric air, or the air in the condenser?

Mr. Abbott: The atmospheric air.

Mr. Alberger: Naturally, if you keep the water away from the atmospheric air it will keep its temperature better; and, furthermore, you keep the water free from air, and in that way avoid the troubles that have been found in connection with boiler plants using water from condensers that contained air and acted on the tubes by oxidation. The British Admiralty have gone into this matter rather thoroughly in the last few years and they find that if you keep the air from the water and the water from the air this corrosion does not take place in the boilers. The ordinary wet-air pump takes the water of condensation from the condenser and also the air from the condenser, and then mixes them together during the process of compression of the air. The aerated water passes to the hot well and the mixture is pumped into the boiler; some of the air escapes into the atmosphere, but the portion that reaches the boiler mixes with the steam when the water is evaporated. If the air is kept entirely separated from the water and the water not allowed to come in contact with atmospheric air, after it once leaves the condenser it remains out. This process reduces the amount of work on the air pump and avoids corrosion by oxidation.

Mr. Abbott: Referring to the Commonwealth Electric Company's installation, in Chicago, with which Mr. Alberger is familiar, is it possible to improve on that by keeping the water pumped from the condenser entirely free from contact with air?

Mr. Alberger: The feed water in that case is practically free from contact, except at the surface of the water in the hot well, which has a cover on it. It could be kept entirely away from the atmospheric air by putting something on that surface to keep the air from the water. But it is so small a surface—perhaps three or four square feet—that I think the absorption that occurs there is extremely small. It may be guarded against by putting a floating cover on that surface, but there is probably no reason for going to that trouble.

The President: We will now have the paper on "The Mechanical Stoker and the Human Operator," by Mr. Edwin Yawger, of Pittsburg, Pennsylvania.

Mr. Yawger presented the following paper:

THE MECHANICAL STOKER AND THE HUMAN OPERATOR

The mechanical stoker is an accessory to an art, and the man who operates the stoker is an accessory to the same art. The mechanical stoker is not a thing by itself. It will not in any way alter the fundamental principles of the combustion of fuel. It is a part of a system, of which the air and gas passages, the baffles and the stack, as well as the operator, are correlative parts. Rankine, in his manual of the steam engine, enumerates 17 parts and appendages that go to make up a boiler furnace. His definition covers practically every part of a boiler equipment, except the vessel that contains the water and steam, and no builder of stokers should assume to offer his machine to a customer unless he is competent to submit a complete furnace design, properly calculated for the conditions of the particular case. Probably more failures have been due to neglect of this requirement than to inherent faults of stokers as machines.

It is evident from the broader view of the appurtenances of a furnace that the mechanical stoker is to be studied, not as a piece of machinery, but as an accessory in the art of fuel combustion.

The size of the plant
The kinds of fuel available
The type of boiler to be used
The preliminary handling of fuel
The conditions of service
The design of all parts of a furnace, and
The character of the operator

These are vital problems in the art, and a happy solution of all of them would greatly reduce the mortality record of the mechanical stoker.

Much of the literature on stokers and on combustion in general consists of records of various performances, in which, as a rule, some one feature is prominent and others more or less ignored. A vast majority of boiler trials are utterly unreliable, and even the most reliable contribute little assistance to commercial judgment.

Mr. Bryan Donkin, in his book *Heat Efficiency of Steam Boilers*, gives a careful analysis of 425 boiler trials. His conclusion from this array of data is best given in his own words:

"When making these summaries, the author at first thought he might be able to draw from them the conclusion that some one type would prove to be more economical than another."

"It is quite clear that much more depends upon how a given boiler, of whatever type, is worked, with clean or dirty surfaces, good or bad combustion, etc., than upon its form, internal or external fires, water or smoke tubes, or the particular way the differently shaped heating surfaces are presented to the furnace and hot gases."

When 400 trials, carefully selected and analyzed, fail to produce any general law, it is evident that another point of view is necessary for broad practical conclusions.

Leaving out, then, the question of detailed tests, it will be the object of this paper to present some of the general considerations that bear on the art of combustion of fuel in boiler furnaces.

The mechanical stoker, as a machine, must possess many points of excellence in order to contribute fully to net commercial economy. First and foremost, it must be so designed that it will continue to supply heat to the boilers in spite of accidents or unfavorable conditions of fuel and service. If heavy clinkers form they should be capable of easy disposal. If the actuating mechanism fails, it should be possible to continue firing by hand manipulation. If grates break, it should be possible to replace them without drawing the fire. In addition to these primary requirements are the numerous details that must be worked out in all their relations before the full measure of fuel and labor economy can be realized.

I believe that next to the matter of continuous operation, the most important feature of furnace design lies in the handling of the air for combustion. A noticeable thing about records of boiler trials is the general lack of uniformity of results under apparently similar conditions. Unfortunately, the factor that enters most largely into this variation is seldom recorded, namely, the relative amount of air consumed. In furnace combustion the fact is often ignored that air is a fluid with a definite specific gravity and a consequent inertia.

No one would expect water mains to be efficient if con-

structed with diversified cross section, sharp turns, and odd corners. Yet it is common to build furnaces in which the gases meet with improper deflection, unnecessary obstruction and restricted passages. Sometimes the ash-pit and its doors are arranged in such manner that the air by its inertia seeks passage through a restricted area of the fire, usually the rear. I have in mind one case where a hopper-bottom ash-pit being open at the front furnished the principal channel for incoming air, which was directed against the rear of the fire, thus causing airholes and a reduction in capacity and efficiency. In some cases a great loss in draft efficiency is caused by the clashing of burnt gases as they issue from various boilers into the smoke connection. I know of a case where two boilers were fitted with a vertical uptake, extending over both boilers. An increase of 25 per cent in the efficiency of the draft was accomplished by placing a partition in the uptake, to separate the gases issuing from adjoining boilers.

It is a matter of common observation that there is frequently a considerable variation in draft in different furnaces where a number are connected to the same stack.

When the furnace is hand-fired, all the losses due to the improper manipulation of the air supply are rendered much greater. An indication of this can be obtained by noting by means of a gauge the variation of draft in the fire chamber during a cycle of firing.

I believe it is the practice of boiler manufacturers to establish a fixed arrangement of baffles. The furnace specialist goes further than this, and arranges the baffles to conform to the nature of the service, and the amount of draft in the particular case.

Accessibility is a prime requisite, and that stoker will give the best service in which the condition of the fire can be seen, and obstructing clinkers dislodged without the opening of doors.

In view of the prevailing tendency toward the use of large boilers, stoker design must permit of a corresponding expansion of grate surface. In many cases 500-hp or 600-hp boilers, instead of being fitted with the proper amount of grate area, as determined by the draft and weight of coal to be burned, are expected to give results on a restricted grate, simply because the design does not permit the proper area.

The data at hand on the question of durability offer, if possible, a wider range than above indicated for boiler trials in general.

The peculiar thing about reports of stoker repairs is that records cover only the two extremes of experience. In a few plants the small cost of repairs being a matter of pride, a segregated record is kept of stoker repairs. In other plants, more unfortunate in design and operation, excessive repairs are often reported. The range in this respect varies from half a cent or less per ton of coal fired, to 12 cents in extraordinary cases. In the large majority of plants between these extremes there is no record available.

It should be noted that the life of a boiler and a furnace should be logically reckoned, not by the year, but by the gallons of water evaporated and the number of tons of coal consumed.

The foregoing requirements are generally understood and accepted.

Other questions of furnace design no doubt have two sides, with advocates for each. A number of makers construct furnaces calculated to reject the refuse continuously and automatically, the argument being that this reduces the labor required and adds to the effectiveness of the operation. On the other hand, it is claimed that continuous discharge will carry over a considerable amount of combustible when fires are forced, while with light firing there will be a thin zone in the fire near the discharge point that will admit an excess of air; also that large clinkers will occasionally fail to pass through an otherwise automatic discharge.

The extent of the fire-brick arch over the fire in furnaces operating with progressive feed is sometimes subject to discussion. The presence of an arch sufficient to reflect heat on the fuel until it is well coked is always recommended. It is argued, however, that the external fire chamber, with its full-length arch, throws back all of the radiant heat upon the fire, thereby increasing the rapidity of combustion and insuring its completeness. Other authorities state that it is better to expose the heating surface promptly to the highest possible temperature, to this end making use of a large proportion of direct radiation. Rankine states that about one-half of the total heat from the combustion of coal is given up in radiation. The open fire, there-

fore, would project a greater quantity of heat against the first row of tubes, with a tendency to intensify evaporation at that point. Experiments made by the Northern Railway Company of France showed that evaporation around the fire-box of a locomotive boiler averaged seven times as great per square foot of heating surface as the rate in the flues.

There is no increased danger to boiler tubes by reason of high temperatures. The rupture of a tube is invariably due to some cause within itself, either a flaw in material or the presence of scale sufficient to interfere with the releasing of steam. With these facts in mind, and with a view to reduce as far as possible the loss by external radiation and air leakage, it seems the logical thing to design an arch deep enough to insure the absence of combustible gases in the flues, at the same time permitting a liberal amount of direct radiation.

Judging from the number of 60-foot stacks in use, especially in steelworks, there would appear to be a wide difference of opinion on the subject of draft. If I were asked to specify a single improvement in furnaces that would net a greater saving than any other, the reply would be "double the height of all the stacks now in use." Intensified draft will work wonders.

First—It will permit the burning of more coal per square foot of grate, thereby increasing furnace temperature. The burning of more fuel per square foot of grate surface, and the consequent high temperature, is in itself an element of economy, illustrating one of the fundamental laws of thermodynamics, which states that efficiency is dependent on the range of temperature in the working medium.

Second—It will make combustion complete at a point nearer the coal; that is, the flame will be shorter, and the excess of air will be less. This condition is due to the fact that a strong draft rushes among the fuel at high velocity, causing a more intimate mixture of air with the inflammable gases.

Third—The same volume of gas at the same temperature will give up more of its heat when passed rapidly than when passed slowly over the same heating area. Many experiments have been made to determine a law governing the effect of speed on the liberation of heat from gases, but the results are variable. All agree, however, that the effect is important.

It is plain from this that the stack or draft apparatus has

a function not usually accorded to it; namely, that of overcoming friction in gas passages induced by high speed of gases. It is considered by many a point of good management to reduce as much as possible the internal friction in furnaces, but if this is done at the expense of speed of gases, the result will be a reduced capacity and a higher stack temperature.

Lack of space forbids taking up other points that are quite well known but often overlooked. For instance, that soot is more fatal to economy than is scale, but not so fatal to boilers, and that under no circumstances does water do duty as fuel.

However perfectly the design and construction of the furnace is carried out, the demands of the art are only half satisfied. The plant must be operated, and the reign of eternal vigilance has just begun.

It is common experience that no part of a power plant is subject to so much neglect as are the boilers. The reason for this lies in two inevitable weaknesses of human nature.

First—A reluctance to perform a dirty and disagreeable task.

Second—A reluctance to perform any task when its results are not apparent to the observation.

An engine operator may build up a reputation by giving such attention to his engines that they will not offend the eye or the ear of the observer. The chances are that if his engine looks clean and runs quietly, it is in fact in good order; but the external cleanliness of a boiler would argue little as to the absence of scaled tubes, soot-choked passages or broken-down baffles.

Some years ago I became partly responsible for the operation of a large mechanically fired plant in Pittsburg. There were 16 boilers in the plant, and I was asked to determine why it seemed impossible to secure sufficient steam for the engines. I made a brief examination of the boilers, and found that the stack draft in the different batteries ranged from .45 inch to .7 inch of water, and that stack temperatures varied from 450 degrees to above 700 degrees. The general condition inside the furnaces seemed obvious. I agreed with the management to pick out a man who would enter their employ and have full charge of the boiler plant, with the expectation that a change would soon be apparent. An inspection by this man showed that in some cases soot had accumulated in such quantities as to choke the gas passages. This explained the low draft and temperature in

some of the stacks. In other cases the baffles were broken down and displaced to such an extent that the gases made practically one pass through the tubes and escaped at high temperature. This gave the key to the other extreme stack condition. It was found, by a little close observation, that the attendants reported the external cleaning of the tubes without going through the formality of doing the work. A short period of personal supervision served to put the plant in such condition that steam was easily supplied by 14 boilers instead of 16. This happened in a stoker-fired plant; it would have been worse in a hand-fired one, because the same human nature would have been there, only more of it. It is evident that such delinquencies on the part of attendants work equally disastrous results, whether the plant is stoked by hand or by machine.

There is another phase of human nature that has an important bearing on the comparison of hand *versus* machine firing which probably furnishes the stoker manufacturer with his strongest argument in favor of the superior fuel economy of the mechanical stoker. It is the well-known fact that there is a wide variation in the efficiency of individual firemen in the actual manipulation of the fires. I am told by the superintendent of motive power of one of our greatest railroads that his company has for a long time maintained a system of rewards, based on the economy in coal obtained by the different locomotive firemen. Basing observations upon the records of a large number of firemen, who have been under the system long enough to establish a personal average, it is found that certain individuals maintain a higher average of rewards than others throughout a long period of service. If, therefore, the company could secure a force of firemen, each one of whom could equal the best average, there would be a saving in fuel amounting to many times the sum required for premiums.

During the World's Fair I was called upon by the judges to conduct some comparative economy tests on traction engines. The tests were for the purpose of determining the fuel economy of boilers and engines combined, when running at constant load, furnaces being fired by the manufacturers' expert firemen. In five engines tested there was a variation in results of about 15 per cent. The steam distribution and the furnace and boiler design were quite similar in all five engines, and it would be

safe to assume that their inherent efficiencies would not vary more than five per cent. The further difference, therefore, of 10 per cent should be charged to the variation between expert firemen.

One universal result of the substitution of mechanical for manual methods consists in a greater uniformity of product, and from the nature of the operation it is possible to maintain a stoker at or near its highest efficiency. To obtain this very desirable condition it will be necessary to start right by making a competent engineer responsible, not only for the selection of the machine, but for the unity of design of the entire furnace, from ash-pit to top of chimney. This responsibility is often assumed by stoker builders, and some of them refuse to make an installation unless full and satisfactory information is furnished covering all the essentials of the furnace.

To maintain a boiler plant at its highest efficiency is not a complex problem, but enough has been said to show that it requires constant and intelligent supervision. It is its capability of responding to intelligent supervision that renders mechanical stoking superior to the human kind. The functions of the machine are varied, when necessary, by positive adjustments, and changes in adjustments can be governed by definite rules easily within the comprehension of the dullest operator. I should say in general that any chief engineer of a station, who himself is capable of operating successfully a mechanical furnace, can, with a reasonable amount of attention, secure uniformly good results throughout a large plant.

A daily inspection of the fires will assist as much as anything, remembering that a white-hot fire is an indication of all-around economy.

Recording instruments of various kinds will be found useful, especially in mechanically fired plants. Probably the most useful record obtainable in connection with furnace operation is a record of the amount of air supplied. With the uniform conditions due to mechanical stoking, such a record gives a fair indication of the degree of efficiency of the furnace. This record is obtained in many plants by an apparatus for the continuous analysis of flue gases. The use of a draft gauge, attached permanently and showing the draft in the fire chamber, will give an approximate idea of the amount of air consumed. A diminution in draft at this point indicates air holes and an excess of air, while a great increase will indicate too great a thickness of fire and the probable presence of CO in the flue.

It will be noticed that an expert stoker fireman, in running a test, will keep his fire gauge at that point which indicates the proper thickness of fire.

Many reports find their way into print condemning wholesale the use of stokers, and many reports get circulated of expensive installations being placed on the scrap pile. It is just possible that in some of these latter cases the mistake occurred, not in the purchase, but in the discarding without making sure that a correction in some other part of the system would not have removed the difficulty. Misfit installations are fortunately decreasing in number, and there are now millions of horse-power of boilers machine-fired in the United States.

A proper appreciation of any art is obtained by a study of its masterpieces, and an engineer who has full knowledge of all that contributes to the success of the best actual installation will be best able to duplicate that success in other situations.

DISCUSSION

THE PRESIDENT: Mr. Yawger's paper is open for discussion. Mr. Parker, have you anything to say on this paper?

MR. C. H. PARKER (Boston): The main point seems to me to be the question of fire temperature. The higher the temperature of the fire, the better the fire efficiency. It is shown clearly in all flue-gas analyses that with low fire temperature and a low number of pounds of coal burned per square foot of grate surface you will have a large excess of free oxygen. When your fire is run up to 40 or 45 pounds of coal per square foot of grate, the excess air is brought down to something like 30 to 40 per cent above the theoretical requirements and the fire is a dead white. In our practice, however, we find that the heating surface of the boilers as ordinarily installed will not take up the heat as given off by this fire and that the most economical point in which to work is somewhere in the neighborhood of 25 per cent above the boiler rating. Where it is possible, with an even load condition, the maximum economy would come by reducing the grate area, burning a greater number of pounds of coal per square foot of grate surface, and working the heating surface at about 25 per cent above the rating.

THE PRESIDENT: Mr. R. S. Hale, of Boston, has sent

in the following contribution to the discussion of Mr. Yawger's paper.

MR. HALE: Mr. Yawger's paper is very interesting, but there is one point on which I should like to advance a contrary view, and that is in regard to the saving by increased draft. I have made and analyzed a great many boiler tests, and it is my firm conviction that, other things being equal, the less draft that is used the higher will be the efficiency. If it is a question of getting a greater capacity, of course a greater draft must be supplied. If it is a question of burning more coal per square foot of surface and getting the same capacity as before, which, of course, means cutting down the grate surface, then of course more draft must be supplied; but other things being equal, the less the draft used the better will be the efficiency of evaporation.

The third point advanced by Mr. Yawger in regard to the saving made by increased draft—that the same volume of gas at the same temperature will give up more of its heat when passed rapidly than when passed slowly over the same heating area—is a fallacy in so far as applied to this question. If the conditions—that is, the output of steam—are to remain the same, then the amount of coal and amount of gas must be reduced in order to gain any better efficiency and must pass more slowly over the heating surface. If increasing the draft causes them to pass more rapidly, it could have none other than a bad effect.

The reason that the best efficiencies are gained with a small draft is that this makes it necessary to fire more carefully in order to keep up the capacity and hence reduces the amount of air used, reducing the loss by the heat of the waste gases and also causing the gas to pass more slowly over the heating surface, giving the gases more time to give up their heat.

I will repeat that there are, of course, many cases where an improvement in the plant as a whole is made by increasing the draft, but that, other things being equal, the highest efficiency will be gained by the smallest draft.

(On motion, the meeting adjourned until ten o'clock on Thursday morning.)

ORDER OF BUSINESS

THURSDAY, May 26, 1904.

FOURTH SESSION, 10.30 A. M.

1. Paper—"Electric Light and Power Plants in Connection with Ice Plants." By C. L. WAKEFIELD
2. Report—Decorative and Sign Lighting. ARTHUR WILLIAMS, Reporter
3. Report—Advertising Methods. LARUE VREDENBURGH, Reporter
4. Report—Committee on President's Address. HENRY L. DOHERTY, Chairman
5. Report—Committee on Purchased Electric Power in Factories. W. H. ATKINS, Chairman

FIFTH SESSION, 2.30 P. M.

1. Report—Committee on District Heating. E. F. McCABE, Chairman
2. Report—Office Methods and Accounting. FRANK W. FRUEAUFF, Reporter
3. Paper—"A Proposed System of Standard Instruments for Operating Companies." By H. P. DAVIS
4. Paper—"Single-Phase Power Motors for Electric-Lighting Stations." By W. A. LAYMAN
5. Report—Committee for Investigating the Photometric Values of Arc Lamps. HENRY L. DOHERTY, Chairman
6. Report—Committee on Analysis of Flue Gases. HENRY L. DOHERTY, Chairman
7. Wrinkles—CHARLES H. WILLIAMS, Editor
8. Question Box—H. T. HARTMAN, Editor
9. Paper—"Oil for Insulating Purposes." By C. E. SKINNER

SIXTH SESSION, 8 P. M.

1. Paper—"Types of Large Water-Power Installations." By DR. F. A. C. PERRINE

EXECUTIVE SESSION

1. Report—Committee on Relations with Kindred Organizations. JAMES I. AYER, Chairman
2. Report of Treasurer
3. Report of Finance Committee. H. H. FAIRBANKS, Chairman
4. Report of Executive Committee
5. Report—Committee on Amendments to By-Laws. HENRY L. DOHERTY, Chairman
6. Report—Committee on Nominations. P. G. GOSSLER, Chairman
7. Report—Committee on Standard Rules for Electrical Construction and Operation. CAPTAIN WILLIAM BROPHY, Chairman

FOURTH SESSION

President Edgar called the meeting to order at half after ten o'clock and announced the first order of business to be the paper on "Electric Light and Power Plants in Connection with Ice Plants," prepared by Mr. C. L. Wakefield, of Dallas, Texas. As Mr. Wakefield was unable to be present at the meeting, the paper was read by Mr. C. R. Maunsell, of Topeka, Kansas.

ELECTRIC LIGHT AND POWER PLANTS IN CONNECTION WITH ICE PLANTS

I offer an apology, to begin with, for approaching a subject of this kind with so little data, and practically all that I am about to say is based upon my own experience. Correspondence with about 50 plants supposed to be operating ice and power plants together, resulted in showing that very few were actually doing so, and these, with three exceptions, without purpose—by accident, as it were. It is strange how many operate by accident, which proves how long-suffering is the "Great Architect." I recommend that the association try to have careful data kept for the coming year on this subject and have the results tabulated.

It can be accepted as a general proposition that anywhere south of that much-heard-of Mason and Dixon's line, electric lighting and power plants can be operated in combination with ice-making plants, where steam is the motive power, advantageously to both industries.

To many members of this association the art of making ice is probably entirely unknown; therefore, I beg your indulgence to state briefly: Ice is made by the rarefaction of gases or the evaporation of liquids in inclosed pipes, the heat effort necessary to do this work being taken from a surrounding medium, a non-congealing heat conductor, which in turn gets its heat from water, in cans or on plates, which it is desired to have frozen.

Distilled water is generally used for making ice, for the sake of purity and clearness of appearance; more especially the latter. This water is distilled from the steam exhausted from the ammonia pumps where the compressor system is used, and from separate distilling apparatus where the absorption process is used. Nearly all modern ammonia pumps will freeze 20 per cent more water than their exhaust will furnish, and as the absorption process requires a separate distilling apparatus all the water that can be obtained from other sources is an advantage easily seen.

Distilled water must be kept by itself, as any mixture, however slight, with undistilled water will cloud the ice. It is also

true that the water must be kept as free of air as possible. Nevertheless, it is practicable to take distilled water from a pipe condenser maintaining a vacuum at the same time.

As to the question of labor: We operated a 300-kw alternating-current plant with the addition of one oiler and one fireman more than our regular force. We were operating this in connection with a 100-ton ice-making plant of a compressor and can system.

It is, of course, not good business to start such industries except where a market is already prepared or on ground that will yield to the plow, but with these conditions in the right shape, the advantages of the combination suggested are seen to be: *First*—The employment of labor for the year around that would otherwise have little to do, but still must be kept on hand. *Second*—A saving in the use of water that would otherwise go to waste. *Third*—A saving in the condensation in steam pipes and headers, which can be almost constantly employed. *Fourth*—The steady load on boilers, with the advantages of which you are all familiar; and upon this point the following is true:

In the warmer climates all business houses close early and people sit much out of doors in the summer-time. The load on the electric machines, therefore, is very light; in our experience not much over half in summer what it is in winter, and not more than one-fourth in quantity and length of time. While the load on the ice plant increases as the summer advances, and decreases as the winter comes on, it is also practicable to slow down or close down the ice machines for a short period during the peak of the load on the electric plant.

I believe it entirely practicable to operate the ammonia and water pumps electrically so as to give a more even load on the generators.

I have found it much easier to get an engineer posted in electricity than one who could operate an ice plant. Electricity seems to present so many possibilities to the imagination that men seek to follow that trade, both as to theory and practice, who should be writing "fairy stories" on other subjects. I present this as one of the minor difficulties in the way of these combinations.

The fuel cost per ton of ice has a wide range; from 350 pounds to 700 pounds of coal being necessary, depending, of

course, upon the calorific value of the fuel and the manner of its use.

The value of cold-storage plants and the necessity for their existence in the south are being slowly grasped, and these offer a still larger field for growth and additions to both ice and electric plants.

The only hope I have in presenting this short paper is that it may stimulate more patient investigators than myself to examine this question, bringing to the work a scientific knowledge of both industries, which I do not possess.

DISCUSSION

THE PRESIDENT: Mr. Wakefield's paper is open for discussion. It is a matter that interests many members in the southern part of the country. I do not see why it should not interest us in the North, but it is new to us and we do not know much about it. The southern companies, particularly, have given this subject considerable attention.

MR. GEORGE N. TIDD (Marion, Ind.): I ask Mr. Wakefield if he ascertained the number of kw-hours per ton of ice with the ordinary motor-driven ammonia pumps, or if there is anyone who knows exactly what data there are, especially on the smaller installations of about 10-ton or 20-ton machines.

MR. N. T. WILCOX: I have had some experience and will attempt to give a little information. In Colorado, I had two five-ton machines, with the new process, whereby there was a circulation of air through the freezing water, and we found there that the energy used on three-phase motors was about 75 kw-hours per nominal ton of ice produced.

MR. ARTHUR WILLIAMS: It seems to me that this subject of artificial ice-making and cooling by electrically-driven apparatus is one of the greatest importance in the electric-power industry: that the automatic refrigerating load is ideal for building up power service off the peak. We have a number of automatic electric cooling installations, and from our experience have become satisfied that arrangements can be made to cut off the electric power at the time of the maximum load.

I have in mind an example of the substitution of electric power for steam in which a 30-hp motor was substituted for

a steam engine of about the same size for driving the ammonia compressor and a motor of two or three horse-power for driving a pump—taking the place of a steam pump—by which the brine is circulated. The installation of the plant as a substitute for steam was considered an experiment, because the load factor on the motor is exceedingly high normally and it is the kind of load that offers an excuse to an engineer who wants to increase the central-station bill as compared with the cost of operating his plant; there is also a good opportunity for neglect of the apparatus. If he wishes to increase the bill, the engineer can do so by unnecessarily lowering the temperature of the brine, thus greatly increasing the consumption of power by the motor, and he can find ready excuse to keep the motor in constant operation. In this plant we did find such tricks resorted to; the brine temperature was kept much lower than was required and the motor was operated twenty-four hours a day. As a result of careful oversight, by the raising of the temperature on one hand and cutting off the motor when its use was not necessary on the other, the cost of the service was surprisingly reduced, to the great satisfaction of the customer and of ourselves.

I think that kind of load is very desirable, and I am satisfied that arrangements can be made to cut off the motors at the peak in the winter time; of course, in the summer there is no peak that need be considered.

There is one interesting fact that we have brought out—I do not know whether or not it is generally known—that a ton of refrigeration can be obtained by the expenditure of 1.5 or 1.75 horse-power. The system is economical of space; it offers the widest range of temperature, which ice does not; and with some systems, if not all, with automatic refrigeration there is a better condition of the contents of the ice box. With the use of ice, the surface of meats is subject to deterioration, which, I understand, is not the case with the use of automatic refrigeration; consequently there is less waste, which, figured in the results, might largely offset the additional cost, if there be any, over the cost of ice.

Mr. Gilchrist: I heartily agree with Mr. Williams in his opinion that it is a very easy matter to induce the owners and operators of refrigerating plants to cut off their load at the

time of the acute peak of the lighting company, especially in the northern climates. As I have analyzed the subject, it seems to me that the electric-lighting man who wants to get refrigerating business must do one of two things: he must either arrange to combine his lighting and power with the refrigerating plant, so that the same corps of engineers that takes care of the brine and ammonia machinery can take care of the engine and dynamo machinery, or else he must use his influence to restrict the size of the refrigerating plant. I have figured with a large number of houses in Chicago and we find, as Mr. Wakefield states, that it is very difficult to get good refrigerating engineers, and they are very high-priced men. It takes a much higher grade of man to operate that kind of machinery than to operate ordinary electric-light and power machinery, so if it is a large house and widely separated from the lighting station it will be found that current must be sold at a price that very few of us can make, in order to secure the contract. In figuring with one house in Chicago—while we did not make any proposition, we obtained their views and went into figures with them—as to what price they could stand, contemplating an agreement under which they should cut out the service absolutely from three o'clock in the afternoon till eight or nine in the evening, they satisfied us that they could not afford to pay more than one and a quarter to one and a half cents per kw-hour.

I have found in the case of wholesale refrigerating that in our big cities the question of cartage comes in to a very considerable extent, and as commission houses, butchers, and so forth, are the best patrons of the cold-storage houses, they have added to their cost of cold storage a large cost for cartage. In a great many districts where small commission houses are located it is found that the lower floors are in great demand for the sale of produce, but the lofts in such districts are frequently a drug in the market, and we have been able to convince a few of the relatively small people that what they should do is to put in their own cold-storage houses in the lofts. We have one or two installations—one in particular—where there is an installation of 125 horse-power. Under our Wright demand rates, by careful use of their motors, they earn a rate of practically three cents, and it has apparently been extremely satis-

factory to them. We obtain a revenue of about $80 per connected horse-power per year from this customer, and he is well satisfied and we are well satisfied. Our agreement with him provides that he shall shut off his plant entirely from three to seven o'clock p. m. during November, December and January.

MR. LEON H. SCHERCK (New York): I understand from the title of the paper—"Electric Light and Power Plants in Connection with Ice Plants"—that the author would suggest the advisability of small central stations in the South going into the ice-making business. I look at this chiefly from the commercial side, and I find two very serious objections. In the first place, those of us who are associated with plants in some of the smaller cities will realize, as the larger companies also realize, the advisability of not having the public think that we are grasping too much. Especially is this true where the local councilmen are so intimate with everybody; to go into the ice-making business would tend to make them believe that we were creating too much of a monopoly, which is a very bad impression to have formed. Again, in the smaller cities you are not required to put your wires under ground; franchises for lighting plants are very easily obtainable, almost without cost to those who obtain them, and by going into the ice-making business we may perhaps force the ice people to go into the electric-lighting business. It is not hard for the ice people to secure some very valuable business from the lighting company, from the fact that they run their plant all night and no expense of underground wiring is necessary to compete with the central station in certain districts that are valuable to the central station. I think these points should be considered as well as the technical side of the question.

MR. ANDREW: I think Mr. Williams referred more particularly to small plants, and not to wholesale manufacturers as Mr. Gilchrist suggested. We have found in New York that it is not difficult in plants connected with restaurants to have them lower their temperature just before our peak comes on, stop the compressors during our peak, and keep only the brine-circulating pumps going. In the downtown restaurants the ice boxes are closed before the peaks come on. As regards the class of men necessary to operate this type of machinery, we

have had no difficulty with low-grade men. When ice plants were installed on ships the electrician or an oiler was assigned to take care of them, and the same thing is true in land practice.

THE PRESIDENT: Many of the members of the association have expressed their thanks to me as the president of the Boston Edison company and also as president of the National Electric Light Association for the entertainment that has been provided during this convention, of which we have had ample. I want to say that everything that has been done for you, and every cent that has been spent, has been provided by the local electrical interests in Boston and vicinity—the illuminating companies of the neighborhood and the manufacturers who have offices in this city, and other supply houses and manufacturers of this general district. It is simply the New England electrical interests that have been doing this, and I want to be sure that you all understand that. (Applause.)

The next two papers on the programme are somewhat more elaborate than usual, and in order that the association may not be accused of extravagance I want to say that the first paper is the gift of the New York Edison company and the second the gift of the Boston Edison company, so that the only expense to the association will be the nominal one of accepting what we have given and putting it in the report of the proceedings of the convention. All the elaborate work on both these productions is paid for by the two local companies, who are pleased to present the reports to the association. I will ask Mr. Williams to read his paper first and Mr. Vredenburgh to read his paper next.

Mr. Arthur Williams read the report on sign and decorative lighting.

(Mr. Williams' report will be found in Appendix B. A sufficient number of copies to be bound in the book were presented by the New York Edison company, and the numbering of the folios does not permit of their insertion in the body of the book. The plates for Mr. Vredenburgh's paper were presented by the Boston Edison company.—EDITOR.)

Mr. LaRue Vredenburgh read the following report on advertising methods:

REPORT ON ADVERTISING METHODS

In reporting on "Advertising Methods," your Reporter recognizes the broadness of the theme, and is sorely tempted to philosophize on the general subject of advertising. It is a subject that intrudes itself upon one's notice day and night, all things visible, including the sun, moon, and stars, are forced into service as advertising mediums. Mountains, rocks and rivers, must do their share; the genius of the artist and the poet, in these practical, matter-of-fact days, is pulled from its pedestal of romance and sentiment, and made to do stunts on the stage of commercial publicity. Literary talent can make more money writing "catchy ads." and designing persuasive booklets than by framing epic poems or soul-stirring romances. The preacher can make a good many dollars on the side, if he so desires, by advertising Pears Soap when admonishing his congregation to observe cleanliness which is next to godliness. The "advertising man" is rapidly pushing himself into a position, by using for himself some of the methods that he advocates for his clients, where he is recognized as one of the *powers* in the world of business. It is a noticeable fact that almost any line of business that has been doing fairly well for a good many years without adopting advertising methods, when first approached on the subject, invariably says, — "I am in a peculiar position in this regard; my business is of such a nature that advertising cannot possibly do me any good," but the aforesaid advertising man gets after this line, good and hard, with his hypodermic needle charged with advertising lymph, and pretty soon the germ gets into the blood and almost immediately we have another well-developed case of advertising fever, and the business at once begins to boom.

Your reporter has received a large number of letters from members of the association, in response to his circular in which he asked for expressions of opinion as to the best methods of advertising to be used by lighting companies, and in a great majority of these letters, the writers expressed a lively interest in the subject but admitted a marked lack of experience. In many cases this experience has been confined to

the use of very limited space in their local papers, used in many instances more for the purpose of establishing and maintaining friendly relations with the papers themselves than with the idea of securing business by this means. The consensus of opinion seems to be that up to the present time, or at least to within the last year or two, the spectacular features of electrical application were so marked and the general subject of electricity so interesting on account of its novelty and the element of mystery involved, that it advertised itself, but all are about ready to admit that these features can no longer be depended upon, and that whereas hitherto the chief question has been to increase the capacity for making the supply meet the demand, the ridge is about passed, and from now on more energy must be devoted to marketing the product.

Your reporter finds that very little has been done along advertising lines by members of the association, with the exception of those companies located in some of the larger cities, notably New York, Brooklyn, Philadelphia, Chicago, Denver and Boston, and the last named seems to be the only one where a thorough, energetic and systematic campaign has been prosecuted. You will therefore pardon the necessarily frequent references to the experience of the Edison Company of Boston.

The practice of issuing a monthly publication was first inaugurated by the New York Edison Co., and its *Bulletin* is now in its third year and getting better every month. This example was promptly followed by the Brooklyn, Chicago and Boston Companies, and *The Brooklyn Edison*, *The Electric City*, and *Edison Light*, make their appearance as near the first of each month as editorial procrastination and striking printers will permit. The public appreciation of these is evidenced by their steadily increasing circulation, especially in the case of the New York Company's *Bulletin*, which has grown from an original issue of *twenty-five hundred* to over *forty thousand.*

The difficulty of determining what definite results in the way of increased business accrue from such publications is readily appreciated, but they undoubtedly serve a beneficial purpose in conjunction with other advertising matter in keeping the company in evidence, educating the public as to the advantages offered in the use of electricity, and especially in emphasizing the growth and enterprise of the company itself. Very little has been done by the electric lighting companies in the way of maintaining exhibition departments, where the practical application of electricity to the varied purposes for which it is adapted is demonstrated; in this regard the gas companies have far outstripped us. A few of the electric companies throughout the country have a

motor or two and a few electric fixtures in a corner of their offices, but no especial effort is made to show them or to invite inspection. There are, however, a small number who have opened show rooms and consider them valuable means of advertising. The Syracuse Lighting Company has a very attractive exhibition room with a good assortment of electrical apparatus on view and very artistic lighting effects.

The Citizens Electric Company, of Eureka Springs, Ark., has a small show room in connection with its office, with a fine street exposure and handsome window.

Syracuse Company's Offices and Exhibition Rooms.

The Bennington Water-Power & Light Company, Bennington, Vt., has an effectively decorated show window which must from necessity attract a great deal of attention.

The Edison Company, of Philadelphia, exhibits a number of motors, some heating apparatus, and an assortment of lighting fixtures, fans, etc., in the window on the street floor of its general offices.

The Edison Company of Boston seems to be the pioneer in this line, and has for over four years maintained an extensive and elaborate exhibition department, with eminently satisfactory results. This de-

Office of Citizens' Electric Co., Eureka Springs, Ark.

Show Window,
Bennington Water-Power and Light Co.

partment was the direct outgrowth of an exhibit which the company made at the Mechanics Fair in Boston in the fall of 1898. The extensive interest shown by the public in this exhibit and the universally favorable comment which it elicited suggested to the management of the Edison Company the idea of opening a Mechanics Fair of its own, for the display of electrical apparatus and the demonstration of its utility, together with a display of efficient and artistic lighting, affording at the same time an opportunity for manufacturers to show their various products under favorable conditions. No charge is made for

Edison Booth at Mechanics Fair, October, 1898

the use of space, the only conditions imposed upon exhibitors being that their apparatus remains in the department at their own risk, on consignment for at least one year. Manufacturers have shown a keen appreciation of the opportunity here offered, and from the day of opening this department all available space has been occupied, with a waiting list anxiously desirous of exhibiting their product. On account of the building in which this department is installed being somewhat away from any main thoroughfare, it was deemed necessary to call the attention of the public to its existence, and the advertising resorted to by the company for this purpose may justly be considered the first systematic and energetic effort made along this line. During the months

of October, November and December, 1901, a fifty-line space on the first page of each of the daily papers of Boston was used for the above purpose, the reading matter being frequently changed, calling attention to the department in general, and also to some specific feature of the exhibit. During the same period of time, cards were displayed in the elevated

Exhibition Department, Edison Company, Boston.

trains and a number of engraved invitations to visit this department were sent by mail to customers and others. The effect of this advertising was at once manifest, the number of visitors being largely increased on the very first day of its appearance and showing a marked falling off immediately upon its discontinuance. During the same period of the following year, cards were displayed in the surface cars,

and on account of the difficulty of discriminating in the choice of cars the entire number, some 1700, were used. Some space was again used in the daily papers, and about 1000 posters (seven by nine feet) were displayed on bill-boards throughout the city. A one-half page advertisement was also inserted in all the theatre programs for the same length of time.

An effort was made by the attendants in the department to determine, by questioning the visitors, which method of advertising attracted the most attention, and the conclusion was reached that the posters and theatre programs were of very little service; the great majority of visitors stating that they had noticed the advertisement either in the cars or newspapers; as between these two, it was impossible to decide, as there seemed to be but very little difference. A feature that attracted a great deal of attention during the fall of 1902, was the practical demonstration of electric cooking that was given in this department every afternoon and evening and resulted in the sale of a considerable amount of cooking apparatus by the company that manufactures it, and the consequent additional consumption of Edison current. It might be stated here that this department does not act as a sales agent for any of the concerns represented, but is always glad to put prospective customers and interested parties in touch with the agents or the manufacturers themselves.

The eminently satisfactory results obtained from the advertising done in this connection, in attracting visitors to the exhibition department, naturally had its effect in recommending advertising methods in general, and has resulted in the establishing by the Edison Company of Boston of an advertising department, and in the prosecution of systematic and energetic advertising campaigns, with a view to the direct increase of business.

There are being carried on at the present time four distinct "follow-up" plans for promoting business in the following lines: POWER, SIGN LIGHTING, ARC LIGHTING, and RESIDENCE LIGHTING, with a separate mailing list for each, these lists aggregating about fifteen thousand names. This is done entirely through the mails, and in the first three lines above named, the campaign is to last for a year, during which time twenty-seven separate communications will be sent to each name on the lists.

These communications consist of fac-simile typewritten letters, enclosing either stamped envelopes or return postal cards; illustrated booklets; mailing cards, etc., gotten up in pleasing and catchy styles and so interspersed as to avoid monotony and keep up the interest.

A LIBERAL ELECTRICAL EDUCATION

is to be had free, by visiting our Exhibition Department, which is open to the public daily from 9 A. M. to 10 P. M.

A competent corps of expert demonstrators is on duty to operate practically and explain intelligently the working of every electrical appliance that adds to the ease of living—from curling irons to electrotherms.

THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON

1, 2 and 3 HEAD PLACE

Clean Heat

Is better than dusty heat; electric heat is clean.

The Exhibition Department

(Free to the Public)

—OF THE—

EDISON ELECTRIC ILLUMINATING CO. Of Boston

shows excellent heating appliances and numberless other electric devices of interest to all. Open day and evening.

1, 2 and 3 Head Place

Enter from Boylston Street in rear of Masonic Temple

ECONOMY, CLEANLINESS AND SAFETY

Are three important characteristics of the flexible Edison electric system. Just how it is used, just what wonderful devices it will operate, just how easy to use, just how little it costs, are explained intelligently by expert demonstrators in our Exhibition Department. Open daily from 9 A. M. to 10 P. M.—Free.

THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON,

1, 2 AND 3 HEAD PLACE.

The Ease of Living

Is accentuated and comfort is intensified in many ways by an intelligent use of the electric current—light, heat and power are all supplied from one source.

Our EXHIBITION DEPARTMENT has been opened to demonstrate practically just what electricity can do for you. Come any week day between 9 A. M. and 10 P. M.

THE EDISON ELECTRIC ILLUMINATING COMPANY Of Boston.

1, 2 and 3 HEAD PLACE.

Enter from Boylston Street in rear of Masonic Temple.

An Electrical Horse Clipper

EXHIBITION DEPARTMENT

HAVE YOU NOTICED

General Offices, No. 3 Head Pl.

Electrical Ventilation

saves Doctors' bills; saves your health; adds to the working efficiency of your employees. It will be real economy for you to let our experts talk to you and show you the actual working of a desk-fan or a big electric blower. You are welcome at our EXHIBITION DEPARTMENT any time between 9 A. M. and 10 P. M. FREE.

THE EDISON ELECTRIC ILLUMINATING COMPANY of Boston

1, 2 and 3 HEAD PLACE

Enter from Boylston Street in rear of Masonic Temple.

Two Electric Lights From One Socket.

EXHIBITION DEPARTMENT

Outlying Districts.

General Offices, No. 3 Head Pl.

A Steak

Exhibition Department

(Free to the Public)

—OF—

THE EDISON ELECTRIC ILLUMINATING COMPANY Of Boston.

1, 2 and 3 HEAD PLACE,

Enter from Boylston Street in rear of Masonic Temple.

The Electric Forge

Consists of a tank of water and electricity; come and see it heat iron to a white heat.

Come to see

EXHIBITION DEPARTMENT

any week day between 9 A. M. and 10 P. M. There are many other marvellous electrical devices which our experts will gladly explain to you FREE.

THE EDISON ELECTRIC ILLUMINATING COMPANY of Boston

1, 2 and 3 Head Place

ELECTRIC SEWING MACHINES

Come and see our electrical sewing machines and other household conveniences. Let our demonstrators explain to you the ease and simplicity of the many electrical devices on view in our EXHIBITION DEPARTMENT, open to you and your friends from 9 A. M. to 10 P. M. daily.

THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON,

1, 2 AND 3 HEAD PLACE.

Electric Refrigeration

is a marvelously interesting process; think of cooling your Ice-Box by electricity! Come and see it done and have it all intelligently explained to you by competent experts. For your information we have opened an

Exhibition Department,

where many interesting electrical appliances are shown in operation from 9 A. M. to 10 P. M., FREE.

The Edison Electric Illuminating Company of Boston,

1, 2 and 3 Head Place.

Coffee & Spices Ground by Electricity

Please Notice Further.

General Offices, No. 3 Head Place.

A Dime's Worth of Electricity

Exhibition Department

TAKE NOTICE ALSO

General Offices, 3 HEAD PLACE.

Group of Newspaper Advertisements Calling Attention to Exhibition Department.

The Residence Lighting campaign was designed to run for only four months, namely: February, March, April and May, and to consist of nineteen communications, of the same general nature as mentioned above; but to be of a more dignified tone and in large part intended to appeal especially to the women, among these being a number of very handsome original drawings, made by some of the best artists in the country, presenting domestic scenes and illustrating the various methods of using electricity in the home. These are sufficiently artistic to justify their being framed and hung in the most attractive homes, serving as a constant reminder of the æsthetic possibilities in electrical application.

Of course the personal letters inclosing postal cards or stamped envelopes have elicited the greatest number of replies, but the booklets, mailing cards, etc., have materially helped, as evidenced by the fact that in many cases the letters called forth no reply immediately upon their receipt, but were answered after the interest of the recipient had been stimulated by the printed matter. The sole purpose of these campaigns has been, not the closing of contracts and securing of business directly from the advertising, but simply as an aid to the soliciting department in securing appointments and locating available fields for work, and there can be no question of their having served this purpose

well, for in many cases when most emphatically unfavorable replies have been received, these very replies have opened the door for the tactful solicitor and business has been secured. The advertising department keeps a complete card catalogue of each of the aforesaid lists, with a card for each name, upon which is noted the date and nature of each communication; the date of reply, when any is received, and whether favorable or unfavorable; the date when contract is closed, and class of contract; the amount of original installation, and also subse-

quent installations, and the amount of money paid from time to time by the customers. As soon as a contract is closed, the card is removed from the original file and placed in a file of "customers secured" and a new name substituted. By means of this system it is possible to determine the exact amount of business secured directly from this advertising during the current year, but it is undoubtedly true that more or less comes indirectly as the results of this effort, no record of which can be kept, and possibly next year and even the year after may yield results from this year's work which in justice should be credited to the adver-

tising account of the current year. At any rate, by the use of this system, there is no danger of giving advertising credit for more than its due.

It seems to have been the practice with quite a number of companies to send out in their mail, with bills, letters, etc., printed matter emanating from various manufacturers of electrical supplies, seeking, of course, to interest present customers in special electrical apparatus, and thus induce a larger consumption of current; this is undoubtedly good so far as it goes, and can be worked with satisfactory results, but has little or no effect in adding new customers to the system.

The value of Sign Lighting is appreciated by the companies, as it usually involves a good sized installation and long hours' burning, and some of them, recognizing the value of electric signs as advertising mediums, have added example to precept and are displaying them as their own advertisements.

The Edison Company of Philadelphia has a number of large exposed lamp signs located on the roofs of prominent buildings along the lines of the railroads leading into the city, so placed as to be plainly seen from the trains, and has received a great number of inquiries and a considerable amount of business as the direct results of these signs.

The Edison Company of Boston has maintained for nearly two years, five illuminated sign boards in different parts of the city, each being located at or near a street-car transfer station. These boards vary in size, to accommodate the space secured for them, from 12 feet x 24 feet to 15 feet x 40 feet, made of seven-eighths inch spruce lumber covered with galvanized iron, painted in black background and white lettering, and equipped with adjustable reflectors along the upper edge, in which the lamps are placed. These reflectors are supported by outriggers so constructed that they may be placed in position to secure the best and most uniform illumination upon the boards. These signs are in charge of the inspection department, and are lighted from dusk until eleven o'clock every night, and are also very noticeable and legible during the daytime. While these signs attract a great deal of attention, and serve to keep the company's name before the public eyes, their main purpose has been to encourage the use of similar devices by the advertising public, and since their introduction by the Edison Company they have been adopted by quite a large number, and especially by the bill posters and others who control sign-board space; — these latter appreciating the added value of their space on account of its being made noticeable at night as well as during the day.

The Edison Company of Boston has also maintained for some time


EDISON LIGHT
EAST BOSTON DISTRICT OFFICE
62-64 CENTRAL SQUARE.


EDISON LIGHT
HARDWARE

a large "MONOGRAM" or "TALKING SIGN" at the Dudley Street Transfer, the largest transfer station in Boston. The sign is located immediately in front of the station and in plain sight of the thousands who change cars daily at this point. This sign is made by the Mason Monogram Company, of New York, and consists of three rows of monograms, twelve in each row, thus admitting of quite a sentence being exposed.

This is used solely to advertise the Edison Company and is changed at frequent intervals and operated nightly from dusk to eleven o'clock.

Monogram Sign of the Boston Edison Company.

Forty sentences are thrown out in succession with about five seconds exposure to each sentence, and quite a story can be told in sequence. This sign has attracted an immense amount of attention, so much so, in fact, that at one time the elevated road complained that people were so interested that they blocked the station and impeded traffic. It might be stated here that the Edison Company has received requests from a number of advertising concerns for space on this sign, but, as stated above, up to the present time it has been used only to advertise the company itself.

Both the New York and Boston companies, and possibly others, have recently been placing prominently on the fronts of buildings in process of construction, where the contracts for lights and power have been secured, sign-boards stating this fact, together with the size of the installation and other facts calculated to impress the passerby. These boards can be used again and again, with slight changes in the lettering, and undoubtedly serve a good purpose.

One of the features used by the very enterprising advertising department of the Chicago Edison Company is their Portable House.

This idea is novel in its conception and most interesting in detail. The house is moved from time to time from one district to another, serving as an office and headquarters for the canvassers in each district in turn, and demonstrating artistic house lighting and also the use of electricity for many domestic purposes; it is a portable exhibition department, is tastefully furnished and handsomely lighted, and proves a source of interest and education to the public and is undoubtedly a most valuable advertisement. Another excellent idea that the Chicago Company has adopted is the placing of cabinets in a large number of drug stores throughout the city, containing application blanks, addressed postal

cards, inquiry blanks, etc. together with copies of *The Electric City*, and other printed matter intended for distribution. These cabinets are of handsome design, and are a desirable adjunct to the furnishings of the stores, and without doubt a great convenience, serving at the same time as a valuable means of distributing the company's advertising matter. Some time since, the Edison Company of Boston adopted as a symbol, or trade-mark, an oval design with the words "Edison Light" appearing thereon and the centre of the oval showing an upright incandescent lamp with light rays radiating from it. This design is displayed in brass on the company's electric trucks, and all meter wagons, lamp wagons, and service wagons, and also appears in colors on the illuminated sign-boards referred to above. The "Edison Light" button, carrying out the same design, was originally gotten up for the employees of the company, but immediately attracted so much attention that requests for them poured in by mail, telephone and otherwise, and, these requests being promptly complied with, the button has not only had thorough distribution, in Boston and vicinity, but is in evidence in some rather remote parts of the country.

In compliance with a statute that requires all electric-light poles to be marked with either the name or trade-mark of the company owning them, the Edison Company of Boston has placed upon all of its poles sheet steel signs about nine by five inches made in oval form, reproducing the symbol described above. This not only meets the requirements of the law, but serves to advertise the company as well.

The Edison Company of Boston has also done considerable missionary work in the way of encouraging the use of Electric Automobiles. Beside installing a number of charging sets on its own lines, the company wrote to all lighting companies as well as municipal lighting plants in New England, with a view to ascertaining where charging facilities exist, and then published a small booklet entitled "Advance Information," in which all charging stations known to exist at the time, were given, together with the hours when same were available and the rate per Kilowatt. This was followed in a short time by another entitled "Further Advance Information." A standard sign was adopted to be placed at all charging stations, and also signs to be displayed at crossroads and along the highways, indicating the distance in each case to the nearest station. These the Edison Company had made and distributed throughout New England. Still another booklet similar to the above was issued January 1, 1904, bringing information up to that date, and also giving the names of all users of electric auto's in Massachusetts. Another booklet was printed and distributed, entitled "Personally

Conducted Tour," in which an interesting account was given of a trip made in one of the company's electric auto's from Boston to New York and return, showing a map of the route taken and all charging stations with the distances between them, emphasizing the ones used in charging the Edison battery. All this can justly be considered good advertising, although immediate results cannot be anticipated.

Thus far, your reporter has pointed out some of the general schemes that have been or are now being used in advertising central-station products, and desires from now on to consider more particularly specific kinds of advertising, with a view to determining which are the most valuable. Of course the broad principle applies that "a satisfied customer is the best advertisement," but we must get this customer first. After he is once safely in the fold he can be used as a living advertisement as long as he remains satisfied; but what we desire especially to consider is the best method of securing new customers: —

NEWSPAPERS

There can be no questioning the fact that advertisements in newspapers are read, and their value as a means of introducing novelties or calling attention to special sales or announcing change of location or the introduction of innovations, cannot be surpassed. But as a means of advertising the general business of a lighting company their efficacy can be justly questioned, except when a company has just been established or is entering a new field. There is another element, however, that enters into the consideration of the use of newspaper space, and has been touched upon already in this report, and that is the maintaining of pleasant relations with the papers themselves. This feature is evidently appreciated by the lighting companies. In many of the larger cities, and especially in Boston, the newspapers are large users of current, and in a number of cases have recently abandoned their private plants and have come onto the central station.

The wisdom of keeping the papers in line is self-evident. In order to get the best results from newspaper advertising, care should be exercised in selecting the page upon which same is to appear. In many cases the first page is preferable. Where the business man is to be reached this is undoubtedly the best location, for many busy men devote only a very short time to the papers, often glancing over the first page only, — and a short, terse and striking "ad" is apt to catch the eye, especially if placed in close proximity to strictly news matter; this applies especially to morning issues. In evening papers, which are more apt to be carried home and more thoroughly read, opposite the editorial page is an

Newspaper Advertisements of The Edison Company of Detroit.

excellent location. Where the advantages of electricity in the home are emphasized, and the intention is to appeal to the women, on or opposite the fashion or household page is the best location. In papers published in suburban towns, the best place is near the local items. There is a grave question as to the wisdom of endeavoring to make purely advertising matter appear as news or reading matter; this rarely deceives any one, and if the attempt at deception is evident it is apt to have a prejudicial effect. Put your matter in as an advertisement and nothing else, but make it interesting and convincing. A liberal policy with the papers will often insure reading notices from time to time, which are always valuable and cost nothing. The selection of type and style of set-up is important and all proof should be carefully read and the subject-matter frequently changed. As the subject of electricity appeals to all classes it is not necessary in the larger cities to discriminate between papers. In Boston, the German, Italian, and Jewish papers have been used to good advantage. A prime factor in newspaper "ads" is to make them short and to the point, not trying to cover too many subjects. It is much better to state one fact clearly, forcibly and concisely than to make an effort to cover too much ground to the detriment of the whole. All advertisements should be directly applicable to the season of the year in which they appear. The use of electric fans at the beginning of warm weather, the wisdom of wiring houses during the vacation months, the use of Christmas signs and decorations at the proper season, etc.

CIRCULAR LETTERS, BOOKLETS, ETC.

The method of advertising which has been most largely used by lighting companies, and which has brought the most satisfactory results, is the systematic distribution of circular letters, booklets, etc. A great deal can be said in favor of this method, but its chief recommendation lies in the fact that it makes a direct personal appeal to the people whose custom is desired.

The typewritten letter signed by an official of the company and addressed to an individual has proven itself to be the most efficacious. Such a letter must be framed with tactful care. It must not be too long, must be couched in pleasing terms, and made as personal as good taste and judgment will allow, with a strict avoidance of all technical terms, and must present that phase of the business calculated to appeal most strongly to the recipient. As the main object of such a letter is to elicit a reply, either a return postal card or a stamped envelope should be enclosed, — preferably an envelope, as it imposes a somewhat greater

obligation to reply. Of course an answer, whether favorable or otherwise, opens the way for further negotiations, and it is then up to the soliciting department to make good. As to booklets, illustrated printed matter and so forth, the possibilities are unlimited. The wise-man of old said, "Of making many books there is no end," and this has forcible application in connection with advertising printed matter. The opportunity for the exercise of taste and ingenuity along this line is great. The natural inclination to make each new booklet or folder handsomer and more ornamental than the last is apt to lead to extremes, and extremes should be avoided. A certain amount of illustrating by means of cuts, photographs, etc., is necessary, but it is frequently the case that this is overdone. The use of too profuse illustration will tend to make the pictures overshadow the reading matter, with the result of its being in many cases entirely overlooked, and as the real argument must be embodied in the printed matter, this effect is greatly to be deplored.

Your reporter, a short time ago, experimented with a few of his friends for the purpose of ascertaining to what extent some of the most common advertisements made definite and lasting impressions. A party of friends were invited to his house, and on the walls of one room were pinned a number of the pictures that are always used in advertising some of the commodities which have by this means attained the greatest publicity. All printed matter that might give a clue to the identity of the articles was carefully cut away, and the guests were requested to write on slips of paper the name of the item advertised in each case. An expression that was heard very frequently during the investigation was, "I have seen that picture a thousand times in the street cars, in magazines, in the papers and other places, but do not seem to be able to remember what it is used to advertise." Out of a collection of sixty such pictures the greatest number properly identified by any one person was twenty-one, and the person who had this number was the president of this association.

The conclusion was arrived at, by this test, that very often the illustrations used are made so striking and noticeable that the object intended to be advertised is entirely overlooked. Illustrations used in advertising matter should either be pictures of the actual commodity for sale, or pictures in which the commodity takes so prominent a place that it is bound to be seen and recognized. This rule can be easily followed in preparing advertising matter for the use of electric lighting companies, for the application of electricity for both light and power, lends itself readily to the camera or the free-hand artist. Especially is this so where illustrations of handsomely lighted buildings, electric signs,

Newspaper Advertisements of The Edison Company of Detroit.

etc., are desired, while motors and other electrical equipment can be easily shown in interesting and striking photographs. Illustrations should never be depended upon to tell the whole story, but should be used, — first, to catch the attention; and second, to clinch the argument presented in the reading matter.

As to the reading matter itself, certain general principles should be observed. All statements made should be simple, brief, clear, truthful and dignified, with emphasis on *brief*. The most common mistake in this class of literature is the effort to say too much, and the busy man relegates such to the waste basket. Boil the reading matter down to the fewest possible words, but make each word count.

ONE MORE FOR THE EDISON COMPANY

THE EDISON ELECTRIC ILLUMINATING COMPANY

of Boston

furnishes ALL THE POWER used in printing HEARST'S BOSTON AMERICAN, and ALL THE LIGHTING in its ENTIRE ESTABLISHMENT.
Two Mammoth Presses with a total capacity of ONE HUNDRED AND NINETY THOUSAND papers PER HOUR are operated by ELECTRIC MOTORS, each Press having an individual Motor of ONE HUNDRED AND FIVE HORSE-POWER, run by ELECTRICITY supplied by THE EDISON COMPANY.

One More Illustration of the Wisdom of Using

ELECTRIC POWER

INSTEAD OF STEAM OR OTHER METHODS

Half-page Advertisement of The Edison Company of Boston.

Advertising matter should not attempt to embody sermons or scientific treatises; it may at times "point a moral" — but never "adorn a tale." Originality in advertising is a most desirable feature, but one of the most difficult to attain. Too many bright minds have been evolving novelties in this line, both in methods and matter, in the past to admit of much that is new making its appearance at the present day, but there is no reason why some of the old methods cannot be adopted by the lighting companies to good advantage.

There is no line of advertising in which dignity should be maintained to a more marked degree than in that of electric lighting companies. The subject is a dignified one, the business is a dignified busi-

ness, its origin and purpose are on a high plane, involving one of the great scientific mysteries of nature, and anything approaching clap-trap or cheap and undignified advertising should be avoided. The nature and tone of the matter sent out should be in character with the business, for it can be justly considered as an index of the concern from which it emanates.

STREET CARS

Street car advertising has become quite popular in other lines and seems to be a means of attracting attention in a manner and at a time that must recommend it to many. The winter months seem to be the better time for using street cars for this purpose, for the arrangement of seats in the summer cars is usually such as to make the cards much less noticeable. Your reporter is of the opinion that the cards in cars are pretty generally read; but would advise a strict avoidance of "Street Car poetry." Dignity and seriousness apply here as well as in newspapers and booklets.

ELECTRIC SIGNS

As all lighting companies urge the use of electric signs upon their customers, it is the part of wisdom on their part to use them themselves, and thus prove their faith. Example has more weight than precept, and others seeing your good works may do likewise. All will surely agree that the word which sounds the key-note of the whole question of advertising is *persistency*. A desultory, unsystematic, haphazard method of advertising is an utter waste of time and money. If worth doing at all, it is worth doing thoroughly and well. If it is worth giving a place in the policy of any company, it should be given a prominent and active place, and be put into competent hands. The advertising department should be thoroughly familiar with the commercial end of the business; should understand the company's policy; its method of charging for current; its rates; forms of contract and system of accounting. It should at all times know what branch of the business needs booming, and when and through what mediums the best results can be obtained. Expensive space in newspapers, magazines, etc., is of little value unless properly used, and many a dollar is thrown away because of a failure to get the most value from space employed. A competent advertising man should know the best mediums through which to reach those whom he desires to interest, and the proper and most effective way of approaching them. He should possess a knowledge of the

various kinds and styles of type, with some artistic sense and a general appreciation of the fitness of things, and should understand proof-reading. He should be master of a pleasing and convincing style of writing, and be able to state facts in such a way as to leave no doubt of their being facts. He is the connecting link between the company and the public. He is the cable through which the current of persuasion flows. He is the fuse on the circuit, and should be ready to "*blow*" in case of "overload" or "short circuits."

There is one more feature in connection with a systematic follow-up-plan, which cannot be overlooked here, and which experience has

Interior, Denver Gas and Electric Company's Office and Exhibition Room.

taught those who have used such plans, to be very important, and that is the preparation of a mailing list. In order to avoid a great deal of wasted powder, much care should be exercised in compiling a list. Plenty of time should be taken in its preparation; the entire ground should be looked over and a careful selection of names made with a view to securing only those to whom the proposition can appeal. There are bound to be mistakes in any mailing list, but no efforts should be spared to make these mistakes as few as possible. In an extended campaign a certain proportion of dead-wood is gradually weeded out,

but this is generally a very small proportion, and the weeding is an expensive process. Much of this expense can be avoided by care in the preparation of the lists. An instance illustrating this point was brought to your reporter's attention a few days since by a friend of his to whom a certain manufacturing concern had been sending letters and printed matter, covering quite a period of time, urging upon him the use of apparatus entirely foreign to his business and of a nature which could not possibly appeal to him in any way. The postage alone on this matter sent him amounted to about four dollars. His business

Exterior, Denver Gas and Electric Company's Office and Exhibition Room.

being the placing of advertisements in papers and magazines, he used this very experience as an argument against advertising through the mails, emphasizing the difficulty of securing a reliable mailing list. This difficulty, however, is not an insurmountable one.

In regard to the methods of advertising employed by foreign companies, your reporter has been able to obtain but very few data. There has evidently been but a very slight effort made along this line abroad, with the exception of the company furnishing current in the city of Brighton, England. This company uses the newspapers to some extent

and also distributes some attractive printed matter, and has been able to increase its output very materially in the poorer districts, by installing prepayment meters, thus enabling the customer to pay in driblets, and finds that the people are willing to pay twelve cents per K.W.-hour in this manner who had refused to pay quarterly or even monthly bills that averaged only about six cents per unit. This company has also largely increased the number of its power customers by furnishing motors "free of charge" for the first three months, and after that at a rental charge of ten per cent. Wiring is also furnished by this company and paid for in small installments. While these tactics may not be considered as strictly advertising methods, they still serve to secure the aforesaid "satisfied customer" who is an advertisement in himself.

The lighting companies on the Continent, so far as your reporter has been able to ascertain, do practically no advertising. In the case of the Paris Company, the exorbitant tax which it is compelled to pay for extension of its network has materially deterred it from any aggressive policy for increasing its business up to the present time.

Your reporter had hoped to be able to incorporate in his report fac-simile reproductions of a variety of advertising matter that has been used by various company members of the association. He was deterred from doing so by the fear of making his report too voluminous, but has prepared an exhibit of these for inspection by the delegates.

Sincere thanks for the valuable information given are extended to those members who responded to the circular letters, and with regrets and apologies for its inadequacies this report is respectfully submitted.

LARUE VREDENBURGH,
Reporter.

DISCUSSION

THE PRESIDENT: These two papers are now open for discussion.

MR. SCHERCK: It is perhaps needless for me to say that the paper by Mr. Williams is a most excellent one, as, indeed, all of Mr. Williams' work has been for several years past. Mr. Vredenburgh's paper is also magnificently gotten up and reflects great credit on the writer. I have, however, a word to say in criticism of the paper that has just been read. It seems to me that it appeals most strongly to the companies that need it least, namely, the larger companies of this country. We must not forget that there is but one New York, one

Boston, one Philadelphia, and one Chicago company. There are but very few large companies in this country, and the number of members in our association shows that there is a great number of smaller ones. I suppose that when one is associated with a large company he is apt to forget that there are others not exactly in his class. I have, perhaps, made this mistake myself, as for some eight years I was identified with the interests of one of the large companies. During the past year I have been associated with the owners of a number of the smaller companies in several of the middle and western states, and I find that methods—advertising methods as well as other methods—that can be used successfully in large companies can not be used, even in proportion, in the smaller ones. Expense cuts a much larger figure with the smaller company than with the larger one. You can not afford, when your revenue is small, to maintain expensive advertising and soliciting departments; you can not afford expensive engravings, and you can not afford to secure the services of advertising experts exclusively for this work. At the same time, you must resort to advertising methods perhaps more energetically than the larger company does, because in the smaller towns and cities you will find that people spend money much less freely for lighting and power purposes than they do in the large cities. This is self-evident when looking at the rates quoted in towns of from 40,000 to 150,000 inhabitants. You will find in most cases that the rates in these cities are perhaps half what they are in towns of 400,000 or 1,000,000, or 1,500,000, and you are required to give these rates; otherwise you can not secure business.

I should like to cite to you some of the inexpensive methods that we have adopted for advertising purposes in some of the properties with which I am identified. We are the owners of street-railway properties as well as lighting properties in certain towns, and we find that one of the best and simplest methods of advertising the lighting as well as the railroad business is by the use of small booklets placed in the cars in small metal holders. These booklets are very inexpensive. They can be printed for $1.00 per thousand, illustrated for about 75 cents per week with cuts that are obtained from one of the several advertising syndicates, and by placing in

them a few jokes, which you can get from clipping bureaus, you will find that the people riding home who are anxious for something to read will take the booklets to their homes and preserve them, if for no other purpose than to read the jokes. In a town of 100,000 inhabitants there are some 10,000 or 12,000 of these booklets issued weekly, and we find by observation that most of them are retained. In a town of 50,000 inhabitants we issued 3000 or 4000 a week and found it necessary to issue more of them, as the people read and preserved them. I have some copies of one of these booklets which I will place on the secretary's desk at the close of the meeting, for your perusal.

Another inexpensive method of advertising, especially for power business, is to go to some machine shop or wood-working shop in your city where the salesman of some motor company has installed a 30-hp or 40-hp motor in one unit to do 15-hp or 20-hp work. Take this place and explain to the proprietor how his bills can be decreased by the substitution of motors, one or several, of the right size. After you have done that, take a photograph of the shop on the "before-and-after" principle, and place on the "before" and "after" pictures, respectively, the bills of the shop for a period of one year. You will find most of these business men in the same line of business belonging to some association. Take this matter up at their meetings, and it will surprise you to find how much business you can do and how quickly your power business can be increased by this simple method. The greatest difficulty is to get the proprietor of the shop to go to the expense of, say, \$500, \$1000 or \$2000, as the case may be, to make the changes in the motor installation. I have found it good practice, and one that is not costly, to share part of the expense of the change with the consumer, not by means of a cash subscription, but by rebating or discounting the bill until part of the installation has been paid for by means of these rebates. A clause can be inserted in the agreement that if for any reason the contract is discontinued the company is not responsible for any part of the expense after that time. We have greatly increased our power business in this way. It is not equivalent to lowering the rate, for as soon as part of the amount has been paid by the rebate the rebate can be stopped according to the conditions of the contract.

In the smaller cities you will find few electric signs; but if you select a few prominent locations—say the principal drug store, the principal department store, and so on—and give these parties, not, as I have seen in many places, a poor sign, cheaply gotten up, but a good sign, which reflects credit on both the illuminating company and the consumer, you will find after you have installed five or six of these signs in prominent locations that the merchants will come to you of their own accord and want to figure on an electric sign. You need not give away signs promiscuously; you might say, for example, that you have established a fund of $1000 and the first stores that make contracts for two or three years will have the signs furnished free until the fund is exhausted.

I find that another cheap method of advertising is by means of electric supply houses in the town. Quote them cheap rates for interior lighting; give them, if necessary, free lights for the sign and show-cases and interior lighting, and let some one see to it that the supply people light up the signs every night and that the lamps are renewed when necessary. We have also adopted a policy with regard to supply houses bringing in a certain number of lamps. In one city we give a monthly pass on the street railway to the supply house that brings in the greatest number of lamps. We find that encourages competition. You can, of course, make the reward greater or less, as you see fit.

We have another scheme in which we have got the supply houses to aid us, and that is in the renting of fans. I do not think it is a good proposition for the electric-lighting companies to go into the supply business, as my experience shows that here is a great chance to lose money; but if you can get the supply company to rent fans—and they can do it and make money where you would lose—you will find your earnings greatly increased.

Another thing that perhaps electric-light companies in the smaller cities do not seem to appreciate is the selection of a good location for their offices. You have to get a location that is desirable, as people will not hunt you up. Light up your offices at night and have them attractive. You will find that people will come to you more readily than if the office is in an out-of-the-way place.

I want to say a word about some of the Detroit company's advertising. While very excellent in its general scope, one objection is what you might call the insinuated attack on the gas companies. I do not think it a good plan to attack competitors; it is more advisable to boom your own product. The gas companies could, if they chose, say many things about fires and costs that would be detrimental to our interests. I know of a campaign in one instance where the electric company found it was good policy to enter into an agreement with the gas company not to "say things" about each other—each to boom up its respective business, but not to attack the other.

The best advertisement is a good hustling solicitor, and that is where, especially in the smaller cities, a great mistake is often made. A grocery clerk, or a man who has measured cloth, is selected for the position of solicitor. The solicitor may be recruited with good results from the ranks of wiremen. A course in one of the correspondence schools will do him some good. Let him know what he is selling; it will accrue to your advantage. I have observed in some cases that by the use of proper methods it has been practicable nearly to double the lighting and power business in a year or eighteen months.

Mr. Converse D. Marsh (New York): I will say that the gentleman's remarks are very interesting. He started out by saying that the small companies could not afford the money for advertising that the large companies can. I do not see why they can not. The small company is just as much interested in the returns as compared with the cost of the advertising matter as is the large company. If the large companies found that they did not get a proportionate return from their advertising they would soon have to stop it. It is not simply the amount of money expended that should be considered; it is the income secured per dollar of expenditure. One dollar expended by a small company may mean as much as $50 expended by a large company. Direct solicitation by mail matter is more valuable to the small company than to the large company, for the reason that the man to whom it is addressed has more time to pay attention to it. The average business man in the small town does not receive so much mail as the average business man in the large town.

The gentleman stated that the solicitor is an important medium in advertising. He certainly is. No advertising campaign will do the work unless backed up by a solicitor. The gentleman's theories do not agree. He advertises through booklets in street cars, gets cheap cuts, and lets it go at that. After all, the point to be achieved is to get the business at a reasonable cost, and if you adopt a form of advertising that fits in and interlocks with the work of the solicitor you will get better results than where you scatter booklets around and do not know who is interested. If a booklet were sent out to a man and caused the recipient to be interested in the subject of electricity and immediately thereafter a solicitor saw him, the solicitor could probably close the contract. But how is the solicitor to know where to go, to whom to go, unless you adopt the form suggested by Mr. Vredenburgh and make a reply easy? If you know a man is sufficiently interested to send to the company to have a solicitor see him, your solicitor will be employed on a valuable prospect. I do not believe that the booklets mentioned receive a great deal of attention. I do not believe that people will pay much attention to cheap booklets; but if they do, the booklets alone will not bring them to a point where they will sign a contract. The advertising must be such as to secure the interest of a possible customer, and if you are going to get nearest to 100 per cent out of the advertising you must arrange your plan so that the solicitor will know who is interested in the advertising. Make the advertising so that the people to whom it is addressed become interested, and let the solicitor know that they are interested, and the solicitor will have an easier time getting the business and getting the customers. Without this, much of the advertising appropriation is sheer waste.

MR. BURNETT: I dislike to disagree with our friend who spoke about the advisability of spending but little money in small towns, but in my opinion he is somewhat inconsistent, as I think I can prove by reference to his previous remarks showing the success he had. He says it is not advisable for an electric-light company to attempt too much, for fear the public might consider it rather grasping. I should like to point out one case that has come within my observation in the last few months. There is an electric-lighting company

in a certain city of medium size, and it has kept within the limits of its legitimate business. It has recently tried quite hard to get new business. A telephone company, on the contrary, has decided to go into the electric-light business, and a refrigerating company has reached the same decision. It now remains for the electric company to retaliate by not only maintaining its present business, but, also, by going out into the telephone and refrigerating fields, if it will do the same thing that other people are doing.

I know of a city in which there was a disastrous fire that reduced the load on the stations by 32.8 per cent, and within a period of three and a half months the load was entirely recovered in a district outside the burned area, to within two per cent, and it was done simply by changing the point of view of the central-station company. Previously, the company had taken the position that it was giving pretty decent service at pretty good rates, asked for a reasonable guarantee—one merely worth while, but not prohibitive—and it was not going to take business that was going to hurt it. The company has changed its point of view. It now says, "We are open. We want your business. We will reduce restrictions and knock down the fences in the shape of minimum guarantees; at the same time, we are going to give good service, and we expect fair prices." Its power business has been increased at the rate of over 100 per cent per year, and its lighting business has been increased at the rate of 50 per cent a year.

This company was unable to reply to the circular letters sent out in connection with these two papers, and I will therefore take the liberty of occupying your time for a moment to say what we are doing in regard to sign lighting. We have arranged with a sign company for the installation of enamel panel signs containing 24 lamps—four-cp or eight-cp, plain or frosted, any lettering the customer desires. The customer signs his contract and pays his bill, and that is all. The company purchases the sign, gets a 25-year franchise or privilege for occupying the streets with the sign, installs it through the local wireman, gets the approval of the insurance authorities, furnishes the first equipment of incandescent lamps, furnishes current, furnishes lamp renewals, turns the sign on at half-past five in the winter months and half-past seven

o'clock in the summer months, turns the sign off at eleven or twelve o'clock, as the customer desires, and lights the sign either six or seven evenings in the week, as the customer desires. In return for the service—which averages four and one-half hours per night, every night in the week—the company gets its maximum price for current, gets the entire expense of the installation reimbursed in the course of two years, the interest and depreciation repaid, and makes a reasonable profit. The result has been that within a month or so of the adoption of that policy the expectations have been exceeded, in the sense that while it was anticipated that two signs a week would be placed, the rate is a sign a day. Furthermore, there is a demand from people who want a bigger, better and more expensive sign; and therein, I think, is the proof of the wisdom of the whole policy, because whereas previously the wiring contractors could not sell a sign, now the people want something different and better and are buying the best that can be purchased at an expense of several hundred dollars.

MR. STANLEY A. GILLESPIE (Greenville, Pa.): I desire to ask Mr. Vredenburgh what percentage of replies he received to the circulars and booklets sent out to possible customers?

MR. VREDENBURGH: The circular letters, inclosing stamped envelopes and postal cards for reply, have been replied to at about an average of 56 per cent. Of course, that includes favorable and unfavorable replies.

While I am on the floor, I will ask Mr. Burnett what method was used to notify the public of the proposition of the free installation of signs?

MR. BURNETT: I am glad to say that the public has not been officially notified, for a reason that I do not wish to mention at this time. The nearest approach to a public statement of the fact was an advertisement in the papers, reading "Electric Signs for Everybody." It is not necessary to proclaim a policy of that kind; on the contrary, it is better not to do it. It is better to have the customers tell one another about some good going on than to issue the fact publicly and make a blare about it.

MR. McCABE: I ask Mr. Vredenburgh what percentage of the gross income of his company is allowed for advertising? Referring to Mr. Marsh's suggestion—that the smaller com-

panies can advertise as well as the larger companies—if we advertised on the same basis as the Boston Edison company we should be out of business at the end of the year. Mr. Vredenburgh says that unless your advertising is good and in the hands of competent agents, the company had better not do any advertising at all. I agree with him.

MR. VREDENBURGH: I think the president of the company will answer that question better than I.

MR. CHARLES L. EDGAR: I am glad to say, roughly speaking, that our gross income is $2,800,000. We spend in canvassing 2.5 per cent and in advertising 2.5 per cent, making about $125,000 a year.

MR. BURNETT: I think it is fair to say that no establishment can be expected to spend more than five per cent of its gross income for advertising.

MR. ARTHUR WILLIAMS: A very interesting report may be made on this subject. In a recent month we found our "follow up" system, which is that of sending to customers letters describing the various features of our service, had returned 66 cents of revenue for every two-cent stamp expended.

MR. R. N. KIMBALL (Kenosha, Wis.): Our company had a rather strange application of the use of an electric sign, where a Methodist church was getting up some revival meetings. The sign had changeable letters. It would read "Revival Meetings" one week, and the next week, "Special Meeting Tonight." They have liked it so well that they will use it all the year round.

THE PRESIDENT: I will say that as a result of the decoration at Symphony Hall last night—I do not know how many of you saw it, but both Mr. Comee, the manager, and Mr. Adamowski, the director of music, said it was the prettiest decoration they had ever seen and they were anxious to have it continued indefinitely—I understand that an arrangement has been made to leave the whole decoration in place, except the $C = \frac{E}{R}$, which is to be taken out; but the outside lines and the festooning are to be left there indefinitely.

MR. SCHERCK: Before the discussion is closed I wish to say a word in reply to the gentleman who followed me (Mr. Marsh). I will ask the managers of any of the small com-

panies here—say plants doing from $200,000 to $300,000 business per annum—whether they would consent to spend in one case $10,000 and in the other case $15,000 on advertising and soliciting. I am not personally acquainted with the gentleman who followed him, but I do not think he has had any experience in handling small properties. If anything, I will guess he is connected with a large company. I am afraid some of my remarks were misunderstood. I said that in the smaller companies expenses must necessarily be kept down. You do not get and can not get the same rates that you do in the larger cities. If you will investigate the prices at which current is sold for lighting and power in the smaller cities you will find it is nearly half that at which it is sold in the larger cities. I think your expenses should be run up more in your soliciting department than on strictly your advertising account. I do not believe it is good practice to spend five per cent of your gross income for advertising and soliciting as the Boston people do.

As to the remarks of Mr. Burnett, he said that my remarks were inconsistent, taking into consideration my remarks on the ice plant. In one case we were talking about advertising and in the other about ice-making. I do not see his point and should be glad to have him explain.

THE PRESIDENT: If there is no further discussion on these papers I will declare the discussion closed.

The Chair will appoint a committee on nominations. I am going to make a little innovation this year and appoint a committee of five rather than three, and I will appoint Mr. P. G. Gossler, of New York, chairman; Mr. D. P. Robinson, of Seattle; Mr. Irvin Butterworth, of Denver; Mr. W. C. L. Eglin, of Philadelphia, and Mr. F. E. Smith, of Somerville, as a committee on nominations, and will ask them to report to the executive session this evening.

I understand the committee on the president's address is ready to make its report. The chairman of this committee is Mr. Henry L. Doherty, of Denver.

Mr. Doherty presented the following report:

REPORT OF COMMITTEE ON PRESIDENT'S ADDRESS

We compliment our president on his able presentation of matters important to the association and the electrical fraternity.

HISTORY AND GROWTH OF THE BUSINESS

The reference to enormous and rapid growth of the electrical business is timely and points a possible lesson upon the ease with which this business might be further developed by proper managerial methods, and modesty perhaps restrained our president from referring to the excellent results he is securing from his efforts in behalf of the Boston company. We call attention to this matter in order that none of the delegates shall overlook the advantages to be gained by studying the methods in vogue here.

CONVENTION PROCEEDINGS

Your committee wishes to congratulate the association upon the excellence of the programme for this convention, and the effective work done by the president in the association's behalf.

GROWTH OF THE ASSOCIATION

The president has referred to the extensive growth of the association and has predicted a continued normal growth. Your committee believes that the larger the membership the more effective the influence of the association can be made, and that the association should not only be national in name but national in character. We therefore recommend the appointment of a committee on membership, to secure the co-operation in our association work of all the central stations in the country, if this is possible; the funds of this work to be provided and the work of the committee to be governed by the executive committee. A similar association increased its membership to the extent of 188 new members last year, and the American Institute of Electrical Engineers did even better.

CHANGE IN BY-LAWS

We find that a change in by-laws, as suggested in the president's address, requires the election of a special committee. We recommend the appointment of this committee at once, with instructions to report its recommendations at the morning session, so that the members may have an opportunity to consider the matter before being called upon to vote in our executive session.

TAKING QUARTERS IN THE UNITED ELECTRICAL BUILDING

Referring to the suggestion of our president, we recommend that quarters be taken in the Union Engineering Building.

CENTRAL-STATION DIRECTORY

We bespeak the support of all central-station men and any assistance that will provide a reliable directory of central stations.

THE ELECTRICAL CONGRESS

We recommend the acceptance of the invitation to participate in the Electrical Congress, and urge that the papers to be furnished by the members of this association be distinctly and directly related to the central-station division of the electrical business.

PRINTING PAPERS IN ADVANCE OF MEETING

We commend the plan adopted at this convention of printing the papers and distributing them in advance of the meeting and recommend the continuance of this practice.

RELATION OF THE QUESTION BOX AND WRINKLE DEPARTMENTS

After careful consideration, we see no way of consolidating the *Question Box* and *Wrinkle* departments. We believe that these two branches of work are distinctive, and any change might impair the efficiency of one or both.

ADVERTISING

We note the remarks of the president regarding advertising, and reiterate the opinion of the committee on a former presidential address, to the effect that this work should be handled by a suitable editor and a progress report be made at each convention.

MUNICIPAL OWNERSHIP

We heartily concur in the recommendation of our president regarding the appointment of a committee on "municipal ownership." This committee should be active and aggressive and should have the unqualified support of all officers and members of the association.

THAWING OUT WATER PIPES BY USE OF AN ELECTRIC CURRENT

This practice, while not new, is not generally in vogue. It was started in Madison, Wisconsin, some five or six years ago. We suggest the appointment of a reporter to collect data regarding the methods in vogue for doing this work, proper charge to be made, and instructions for doing the work. The report to be made by September fifteenth, and to be printed in pamphlet form and sent out to all members not later than October first.

EXECUTIVE COMMITTEE

We consider the proposed plan of our president to revamp the executive committee upon more active lines a step in the right direction. We find, however, that such meetings will cost, approximately, $500 each. We therefore have considered it advisable that but three special meetings be held each year, and that the fourth meeting be held at the time of our annual convention. Assuming that three special meetings be held each year, the expense to the association would be, approximately, $1500 per annum. We recommend these three meetings be held the nearest Wednesday to the middle of August, November and February, New York city, or at such place and approximate time as the president may designate.

Respectfully submitted,

Committee, { Henry L. Doherty, Chairman,
G. W. Brine,
H. T. Hartman.

Mr. Ferguson : I move that the report of the committee on the president's address be accepted.

(Motion seconded and carried.)

The President: The report on by-laws was handed to this committee, probably with the intention that it would report

on the by-laws in the report that it has just presented, but we were afterward informed that it was necessary to elect a special committee, and that will have to be done.

Mr. Doherty then outlined the proposed changes in the by-laws.

THE PRESIDENT: I will state in connection with Mr. Doherty's report that the executive committee has formally passed on the recommendations as to the changes in the by-laws and will recommend them at the executive session to-night.

The next order of business is the election of the special committee to take into consideration the proposed changes in the by-laws.

MR. FERGUSON: In view of the fact that it is necessary to elect a committee to consider the changes in the by-laws, I make a motion that such committee be elected at this meeting, with the further recommendation that the same committee act that had in charge the address of the president.

(The motion was seconded and carried.)

THE PRESIDENT: The next business is the report of the committee on purchased electric power in factories, of which Mr. W. H. Atkins, of Boston, is chairman.

The following report was read by Mr. George W. Brine, of Atlanta, Georgia, a member of the committee:

REPORT OF COMMITTEE ON PURCHASED ELECTRIC POWER IN FACTORIES

The committee appointed at the convention of 1903 to investigate the subject at the head of this report, formulated and sent to every member of the association a circular letter in which the most common users of power were classified and certain questions were asked in regard to these classes.

The classification was as follows:

1. Boot and shoe manufacturing
2. Printing
3. Cotton manufacturing
4. Woolen manufacturing
5. Woodworking
6. Metal-working
7. Bookbinding, etc.
8. Paper-box manufacturing
9. Clothing manufacturing
10. Candy manufacturing
11. Laundries

The questions asked were these:

1. Please to give a list of factories in above classes to which you supply power and state horse-power connected in each case.

2. State in each case whether factory is driven by single motor, by motors applied to grouped machines, or by individual motor for each machine.

3. State kw-hours per year sold each factory.

4. State average hours per day each factory is run.

5. What, according to your experience, is the relative efficiency of "individual motors" and of "group drive"?

6. In which of the above cases have you replaced steam or gas engines with electric motors, and what is the horse-power of the engine removed in each case?

7. In these cases, by what per cent, if any, has the cost of production been reduced?

8. By what features of electric power has this reduction been accomplished?

9. By what horse-power, in motors, did you increase your connected load in 1903?

10. What per cent is this of your total increase in connected load for the year?

11. What per cent of increase was this over horse-power connected January 1, 1903; and what per cent did your total connected load increase during the year?

12. Do you supply direct or alternating current?

13. What are your rates for power?

The committee tried to ask such questions as would bring out as much information as possible without making the work of answering so formidable to the larger companies that they would not answer at all.

The small number of replies received, and the fact that only three of the very large companies replied, lead the committee to believe that its efforts were not very successful.

The number of circulars sent out was 462: the number of answers received was 61. Of these, 19 reported that they sold no power to factories; 11 either gave no information or answered but one or two questions, and 31 replied more or less fully. You will readily see that reports from 31 out of over 400 companies will not furnish data upon which to base a comprehensive or definite report.

If we examine the reports with a view to learn what power is being sold to different classes of users, we find that the sale of power to boot and shoe factories is small. Only 10 companies report selling any, and these have a total of 354 horse-power connected. This amount of horse-power is divided among 27 customers—an average of 13 horse-power to each shop.

The showing among printers is much better. Twenty-seven companies report that they have in 375 printing establishments 6247 horse-power. This is an average of 16 horse-power to each office, showing that most of the business comes from small users, although there is one motor of 100 horse-power and there are several of 30 and 40 horse-power each.

Ten companies report cotton factories as customers. There are 48 factories having 3060 horse-power—an average of 63 horse-power to each factory. This is a remarkably good showing, for cotton manufacturers are not inclined to believe that the central station can supply power as cheaply as they can make it.

Only one company reports sale of power to a woolen factory. This company has five customers, with 115 horse-power.

Twenty-three companies are selling power to 172 wood-working shops, where 1953 horse-power are installed. The largest motor in this class is of 60 horse-power, the average installation being 11 horse-power.

The metal workers, especially the smaller ones, have adopted electric power to a fair extent. Twenty-nine companies are supplying 334 shops, which are driven by motors of 6744 horse-power—an average of 20 horse-power to each shop. Forty horse-power is the largest unit reported in this class.

The bookbinder is a very unimportant user of electric power. Seven companies report 15 customers, 69 motors and 306 horse-power; 49 motors of 196 horse-power being in one shop.

Of nearly equal insignificance is the business of paper-box making, but 10 companies having any business of this kind. They supply power to 18 shops having 277 horse-power. In this class, again, we find one shop with 14 motors of 139 horse-power.

The manufacture of clothing has always been a profitable field for the electric motor, but the committee is surprised at the small number of companies having any of this class of customers. Only 14 companies report any clothing factories, but these have 225 customers (and of these 137 are supplied by one company) with 1015 horse-power; the installations average five horse-power. One company reports supplying power to 400 clothing factories, but as all details are omitted the committee could not use the report. Another company, although omitting formal mention of clothing factories in its report, yet supplies power to a very large number, but all of small size.

That the candy lover is found all over the country is proved by the widely scattered points from which 13 companies report a total of 34 factories with an installation of 446 horse-power, an average of 13 horse-power.

Laundries do not come under the head of factories, but the committee included them in its inquiries, as it was supposed that many such shops used electric power. Reports from six companies show but 14 laundries connected, with 14 motors of 61 horse-power. The requirement of a constant supply of live steam imposes a heavy handicap upon the sale of electric power to laundries.

Among other classes of manufactures reported upon, the most important is food products, such as sausages, canned meats, fruit and vegetables, biscuits, etc. Nine companies supply power to 55 factories of this class. These are equipped with 1102 horse-power, the average size of the installation being 20 horse-power.

Six companies report the use of motors in cutting marble and other stone, 20 yards having the same number of motors of 465 horse-power, an average of 23 horse-power per motor.

One important installation is reported from Chicago, which comes under none of the above classes—the manufacture of absorbent cotton and porous plasters. This factory has 35 motors of 160 horse-power.

Other installations worthy of mention are:

2 dye works,	78	horse-power
1 rubber-refining works,	105	" "
2 glass factories,	60	" "
2 breweries,	195	" "
4 ink and color works,	111	" "
1 cotton-seed oil mill,	135	" "
2 fertilizer factories,	135	" "
4 spring-bed works,	126	" "
1 chemical works,	50	" "
1 belting factory,	150	" "
1 tannery,	50	" "
2 cement works,	75	" "
and glove factories having	90	" "

In giving the above statistics, the committee would not have the association understand that the figures of customers, motors or horse-power represent the total installation of the companies reporting. In many cases, as may be seen by referring to the Chicago report, only certain typical and important installations are reported, as it would manifestly be impractical to make a complete analysis of all the company's power business.

The number of steam and gas engines reported replaced by electric motors is not large, but this is owing to the difficulty of getting at the facts as to number and horse-power of such engines, not because the engines have not been taken out, for one company alone has replaced 130 gas engines, besides as many or more steam engines. The reports give so few details that the committee can offer no information upon this point.

Driving machines by individual motors seems to make

very slow headway, if we may judge from the reports received. Only 71 shops report such installations; 187 have their machines driven in groups to a greater or less extent, but the overwhelming majority still operate with a single motor.

With reference to the fifth question, the committee does not believe that any hard-and-fast rule can be laid down in regard to the use of individual motors as opposed to group drive. There seems to be very little information to be had as to the relative efficiency of "group drive" and "individual drive." Managers are very cautious in expressing an opinion upon this point. The few that did offer an estimate, consider that "individual drive" would save from 5 per cent to 25 per cent, according to circumstances. While the average load on individual-motor installations runs from 15 to 30 per cent, as against an average load on group drive of from 30 to 50 per cent on a 10-hour basis, we must remember that the installed horse-power in motors is frequently twice as large with individual motors as compared with group drive for the same number of machines. This means a larger investment and hence increased fixed charges.

In remodeling old machine shops for electric drive, it is impracticable to figure on individual installations of motors for each machine, as the first cost of motors would be very large. The committee would favor for ordinary cases a group-drive system, using motors of from five to fifteen horse-power each. For large tools requiring ten-horse power or over, individual motors are recommended. This would especially apply to large punch shears, beam saws, air compressers and very large machine tools.

In some classes of work, such as printing, engraving and machine-tool driving, it is better to use individual motors even on the smaller machine, in order to secure flexibility in the control of each machine; a great range of speed being very important, and such range as the electric motor will supply can be obtained in no other way.

In wood-working shops the conditions vary so greatly that while group drive is desirable in large shops having steady runs for the machines, at the same time individual connection is much more economical in shops that work their machines intermittently.

The cost of production has almost invariably been reduced

by the substitution of electricity for steam or gas; the principal factors in such reduction being the elimination of shafting, the ability to shut down the power a part of the time, the saving in attendance, and the low rate at which electricity is sold.

In this connection the committee quotes *verbatim* from the report of the Chicago Edison Company, as the words quoted seem very much to the point.

"While there is no doubt but what in the great majority of cases there has been a saving in the cost of operation by the use of electric power, it is hard to get specific data in regard to this. The customer seems to be afraid that if he reports a large saving by the use of central-station service, it may have an unfavorable effect on his future bills for power, and his effort is naturally to keep the bills down as much as possible. A good many, however, have frankly admitted that they are saving money by the use of our service, and we have a number of complimentary letters, notably from customers Nos. 5, 30 and 26. Customer No. 31 on the schedule informs us that his total cost for power, heating and labor is less than one-third of the cost when he was operating an independent plant. Moreover, he has been enabled in one branch of the factory to run a night shift of men, thereby getting double the results out of a ten thousand dollar investment and, at the same time, keeping the power rate down to a minimum. He also tells us that he is enabled to determine the exact cost of each department by having separate meters for each department and in this way determine just what prices he can make on different classes of product. Customer No. 35 claims that this ability to determine the cost of different departments is of very great value to him in determining how low he can go in price on certain classes of goods. There is also the advantage that by charging up the actual amount of power used in each department of a factory the department foremen are made to feel the responsibility for keeping down the cost of the power in their respective departments, and the result is that there is not nearly as much power wasted as before."

The percentage of increase in the connected motor load during the year 1903 varies from three per cent to twelve hundred per cent, the latter figure being reached by a company that had but four horse-power connected at the beginning of the year.

The average increase of the 25 companies reporting was 84 per cent, or, omitting the extremely high figure given above, the average of 24 companies was 37 per cent.

The average increase in connected load during 1903 by 17 companies reporting was 23 per cent, the extremes being 10 and 80 per cent.

It would seem, therefore, that the power business was increasing in a larger proportion than the light load, a condition that is exceedingly encouraging, for you all appreciate the importance of the motor load in evening up the low places in the daily output.

Nearly all companies appear to supply alternating current for power; several furnish both alternating and direct, and five deliver direct only.

With very few exceptions the companies report that they sell power by meter, the rates being from two cents to fifteen cents per kw-hour, the usual range being from four to ten cents.

The committee omits all data upon the amount of current used by different classes of work, for the reason that reports which could be used were received from but 13 companies, and generalizations based upon so few figures would be of little practical value.

An examination of the reports received leads to the conclusion that the sale of electric power by central stations to factories has been limited largely to such industries as have to carry on their business in the centres of cities or towns where space is costly and where the trouble and danger of steam engines become large factors.

The great industries of boots and shoes, cottons and woolens, usually produce their own power.

Among printers, we have a large patronage from "job shops" and a good proportion of the newspaper offices, but practically none of the book printers, whose "runs" are long and whose "make-readys" are comparatively short.

The committee sees but two ways by which to reach the large consumer. First, to reduce wholesale rates until they become attractive.

In looking over the reports we notice that wherever the rates* are especially low the motors in circuit are especially large and the number of wholesale customers is also large. Although a reduction in rates is very sure to bring large

customers, the committee does not believe that this course is necessary.

The alternative suggestion—to educate the prospective customer—is much more rational and more satisfactory in the end. Although electric power has been in use for 15 years, yet it is not the first power of which a man thinks when he is about to start a new factory. If the central station could have its solicitor on hand to explain the advantages of electric drive over mechanical drive before the prospective customer has purchased his gas engine or steam engine, or made his contract for power from a belt, a great amount of business might be obtained which is lost simply through unfamiliarity with electric power on the part of the power-using public. In this connection it is of the highest importance that the solicitor be thoroughly conversant with different manufacturing processes, and be a man of great power of observation, so that he can take in the situation quickly and give the customer the needed points which will "tell" and turn the scale to electric drive supplied from central station.

After a customer has been secured he should not be left to his own resources, but should be advised as to the number of motors to purchase and their arrangement. Careful attention to the details of installations at the time the motors are purchased will effect economies, and these will go to the credit of the central-station service. The customer is naturally quite reluctant to buy several motors, when, so far as he can see, one will do the work just as well; but the solicitor should have at hand facts and figures that will prove conclusively that the extra motors will return a good dividend upon the investment, and that with the individual-motor equipment or the group drive, the central-station can supply power more cheaply than the customer can produce it himself.

One great point of economy which should be looked after is the use of the electric elevator in place of that operated by steam or hydraulic power. In many factories may be found a slow-speed freight elevator driven by belts from the main shaft. This can always be changed over and connected to an electric motor without calling on the elevator makers and at comparatively small expense.

Another important feature in central-station service is the facility with which any single department can be run over-time. This often avoids the employment of inexperienced

help, and enables the manufacturer to respond more promptly to any unusual demand.

Another exceedingly important factor in the advantages of electric power is the ease with which a plant can be enlarged by merely buying additional motors from time to time, instead of taking out and discarding an overloaded steam plant and putting in a new one at enormous expense, or at least adding long lines of shafting and belting.

The ability to move machines about, taking the tool to the work, instead of the work to the tool, is often a great advantage in large establishments, and this may be done with the greatest facility when tools are directly connected to electric motors. The time saved by this arrangement in shops handling large masses of metal would pay a very large dividend on the investment in motors.

The cleanliness of a shop supplied with motors instead of with shafting would be a revelation to one who was not familiar with the results which such a change in power produces.

The committee greatly regrets the brevity and indefiniteness of this report, but the responsibility for that rests upon the members of the association who did not respond to the committee's circular. If the members wish to receive information, they must be willing to impart it, and the committee hopes that when future committees send out their interrogatory letters, they will not be compelled to state that 87 per cent of you failed to respond.

There is so great a variance in the completeness of different reports that the committee adds, as an appendix, the reports received from the companies with which the three members of the committee are connected, as being typical of the reports the committee hoped to receive, but, in most cases, did not.

Finally, the committee would suggest that, if such information as this report contains is of sufficient value to the association to make it worth while to continue the research, then a form be prepared upon which to report such data. This form should be supplied to the members, and should be filled out and sent in at such intervals as may be desirable, whether annually or triennially, as you may determine.

Respectfully submitted,

Committee, { W. H. Atkins, Chairman,
S. Morgan Bushnell,
Geo. W. Brine.

APPENDIX

EXHIBIT A—ATLANTA, GEORGIA

"In accordance with your letter of January 15th, I give you the following data of this company, to be used in connection with the report on Purchased Electric Power in Factories:

Customer Number	Question No. 1 Hp Connected	Question No. 2 Drive	Question No. 3 Kw per Year	Question No. 4 Hrs. per Day
LEATHER				
1	3	One motor	3,014	10
2	5	"	3,248	10
3	27½	Part group, part individual	24,932	10
4	8	Group	3,211	Shop 10, Motor 3
PRINTING				
1	37	Part group, part individual	6,516	3
2	107¾	" "	35,432	10½
3	1¼	" "	1,002	4
4	½	One motor	54	
5	4½	Part group, part individual	4,754	10
6	23½	" "	20,985	10
7	1	One motor	227	Shop 9, Motor 4
8	1	"	1,440	6
9	1	"	434	Shop 9, Motor 5
10	1	"	344	Shop 9, Motor 4
11	1	"	2,210	10
12	1	"	753	4
13	1	"	365	5
14	1	"	781	7
15	1	"	420	3
16	5	Group	5,610	9
17	2	One motor	2,058	10
18	2	"	629	4
19	2	"	294	2
20	2	"	926	Shop 9, Motor 9
21	2	"	1,088	9
22	2	"	1,564	10
23	7½	Group, also elevator	3,442	10
24	9	Group	4,950	10
25	3	One motor	1,508	10
26	3	"	2,520	Shop 10, Motor 6
27	3	"	1,376	10
28	5	"	4,550	10
29	5	Group	512	Shop 9, Motor 1
30	5	One motor	3,847	10
31	5	"	3,960	10
32	96	Part group, part individual	45,408	6
33	14	Group	19,246	10
34	6	One motor	1,972	10
35	10	"	7,123	10
36	11¼	Group	12,566	10
37	10	One motor	4,808	10
38	12	"	10,060	9
39	15	One motor and elevator	13,960	10
COTTON MANUFACTURING				
1	50	One motor	117,252	22

Customer Number	Question No. 1 Hp Connected	Question No. 2 Drive	Question No. 3 Kw per Year	Question No. 4 Hrs. per Day
Woodworking				
1	10	One motor	2,582	2
2	10	"	7,385	10
3	25	"	10,224	10
4	3	"	508	Shop 10, Motor 4
5	3½	"	990	3
6	5	"	2,812	10
7	5	"	182	1
8	11	Group and elevator	760	Shop 9, Motor 4
9	5	One motor	2,378	Shop 10, Motor 4
10	5	"	62	
11	7½	"	768	1
Metal-working				
1	10	One motor	2,016	Shop 10, Motor 4
2	25	Shop and blower	15,675	Shop 10, Motor 10
3	13	"	4,092	10
4	30	2 shops, 1 motor in each	25,615	10
5	15	One motor	1,104	Shop 9, Motor 3
6	15	Group and elevator	3,784	10
7	3	One motor	496	?
8	4	"	1,600	Shop 10, Motor 8½
9	5	"	3,542	Shop 9, Motor 7
10	10	Shop and elevator	2,370	6
11	5	One motor	2,196	6
12	7	"	7,820	10
13	10	"	8,534	10
14	10	"	5,412	10
15	4½	Group	3,838	10
16	1	One motor	108	1
17	2	"	879	1
18	5	"	1,216	5
19	3	"	2,242	Shop 10, Motor 8
20	3	"	1,141	6
21	2	"	360	1
Bookbinding				
1	1	One motor	503	Shop 9, Motor 4½
2	1	"	391	Shop 9, Motor 5
Paper-box Manufacturing				
1	16	Group and elevator	20,692	10
2	7½	One motor	5,056	10
3	10	"	19,072	10
Clothing Manufacturing				
1	26	Group drive and elevator	44,928	9
2	1	One motor	1,578	10
3	6	Group	9,660	10
4	2	One motor	1,066	10
5	7½	"	18,814	10
6	2	"	2,130	10
7	17½	Group and elevator	14,500	9
8	22	" "	15,740	9
9	2	One motor	724	10

Customer Number	Question No. 1 Hp Connected	Question No. 2 Drive	Question No. 3 Kw per Year	Question No. 4 Hrs. per Day
Candy Manufacturing				
1	21	Group and elevator	4,140	10
2	25	" "	4,032	10
3	12½	One motor and elevator	3,750	Shop 10, Motor 2
Paint Manufacturing				
1	15½	One motor	10,004	10
2	20	"	14,052	10
Spring-bed Manufacturing				
1	46	Group and individual motors	48,924	10
2	10	One motor	5,992	10
3	35	Group and elevator	36,020	10
4	35	Group	37,896	10
Mattress Manufacturing				
1	5	One motor	1,276	Shop 10, Motor 4½
Chemical Manufacturing				
1	50	One motor	37,510	10
Stone Cutters, Etc.				
1	7½	One motor	2,274	Shop 9
2	6	"	1,404	" 9
3	7½	"	1,660	Shop 9, Motor 4½

SUMMARY

Class No.	Motors No.	Hp	Drive
1	7	43½	One motor (2), group (1), part individual and part group (1)
2	71	420¼	One motor (27), group (6), part individual and part group (6)
3	1	50	One motor (1)
5	12	90	One motor (10), group (1)
6	26	182	One motor (16), group (5)
7	2	2	One motor (2)
8	4	33½	One motor (2), group (1)
9	14	86	One motor (5), group (4)
10	8	58½	Group and elevator (2), one motor and elevator (1)
Misc.	16	237½	One motor (8), group (2), part individual and part group (1)

Question No. 5, 7½ per cent in favor of individual motors.

Answer to question No. 6:

PRINTING

2—Displaced partial steam plant, 40-hp engine for power, 60-hp engine for light.

32—Displaced partial steam plant, 35-hp.

38—Displaced steam plant, 25-hp.

METAL-WORKING

12—Kerosene oil engine, 6-hp.

14—Displaced gas engine, 4-hp.

CHEMICAL MANUFACTURING

1—Displaced partial steam plant. (Steam plant still used as an auxiliary.)

Question No. 7, Probably about 5 per cent.

" " 8, Electric current sold on meter basis and at very low rates so that customers pay only for energy actually required.

" " 9, 255 hp.

" " 10, 24 per cent.

" " 11, Horse-power connected increase over January 1, 1903, 9 per cent; total connected load increase, 12½ per cent.

" " 12, We supply both direct and alternating current, the alternating-current motors being 60-cycle, single phase, up to 5-hp, three phase over 5-hp.

" " 13, High rate 7 cents per kw-hour, low rate 3 cents per kw-hour up to 10 hp, 2 cents per kw-hour over 10 hp, subject to 10 per cent discount on prompt payment; the kw-hour charged at the high rate being based on the connected load.

In arriving at the answers to questions Nos. 10 and 11, the total number of arc and incandescent lamps connected was reduced to horse-power"

EXHIBIT B—BOSTON, MASSACHUSETTS

"The use of electric power in factories, as the term is ordinarily used is very small in Boston except in two or three lines, namely, printing and clothing manufacturing. The largest use of electric power in this city is for elevators, which of course do not come under the scope of the committee's circular.

We would answer the committee's questions as follows:

Class 1—Boot and shoe manufacturing, none.

Class 2—Printing. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
1	2 -hp	Individual	402
	10		2,585
2	(3) ½		
	1	"	802
3	10		
	15	Group	37,974
	(2) 3		
	4		
	(3) 5		
4	(3) 6	Individual	38,270
	10		
	(2) 15		
	18		
5	1	Single	624
6	5		
	20	Group	19,561
7	1	Single	1,305
8	3	"	1,831
9	1½	"	1,117
10	100	Individual	15,122

Customer Number	Motor	Drive	Kw-hours
11	20 -hp	Single	5,996
12	6		
	50	Group	24,792
	10		
13	1	Single	245
14	1½	"	805
15	1½	"	307
16	1½	"	147
17	5	"	3,085
18	3	"	392
19	1	"	608
20	2	"	1,435
21	3	"	1,691
22	2		
	½	Individual	1,759
	(3) ¼		
23	2	Single	1,084
24	1	"	405
25	2	"	440
26	2½	"	1,197
27	3		
	25	Group	37,744
28	10	Single	16,700
29	10	"	10,532
30	2	"	1,064
31	1	"	172
32	1	"	1,459
33	10		
	15	Group	38,284
	¾		
	1		
	10		
34	(2) 12	Individual	74,469
	(3) 30		
	(4) 50		
35	1	Single	155
36	2	"	1,746
37	1	"	2,506
38	3	"	591
39	3	"	2,288
40	5	"	2,991
41	1	"	262
42	2½	"	1,365
43	1½	"	1,005
44	1	"	280
45	3		
	5	Group	3,459
46	1	Single	567
47	2	"	1,069
48	10	"	6,613
49	1	"	322
50	2	"	2,641
51	7½	"	881
52	5	"	219
53	3	"	1,468
54	1½	"	1,964
55	7½	"	5,294
56	1	"	95
57	12½	"	5,733

Customer Number	Motor	Drive	Kw-hours
58	1 -hp	Single	176
59	1½	"	895
60	1	"	293
61	3		
	20	Group	5,989
	50		
62	2	Single	984
	(2) 6		
	½		
	4		
63	¾	Individual	25,510
	5		
	(7) 3		
64	1	Single	1,181
65	2	"	523
66	1	"	598
67	1½	"	91
68	5	"	7,094
69	7½	"	6,409
70	5	"	3,073
71	2	"	1,048
72	30	"	25,613
73	2	"	1,274
74	1	"	249
75	2	"	802
76	2	"	105
77	¼		
	5	Individual	44
78	3	Single	27
79	3	"	66
80	1	"	27
81	1	"	104
82	1	"	97
83	2	"	869
84	3	"	1,026
85	3	"	384
86	1½	"	218

The synopsis of the above is given below:

Horse-power	¼	½	¾	1	1½	2	2½	3	4	5	6	7½	10	12
No. of motors	4	5	2	25	9	16	2	22	2	12	6	3	9	3

Horse-power	15	18	20	25	30	50	100
No. of motors	3	1	4	2	4	6	1

The total number of printing offices is 86, having 136 motors of 1081 horse-power. Of these factories, 72 are driven by single motors, 7 by motors applied to group machines and 8 by motors applied to individual machines.

Total number of kw-hours, 334,383.

Answer to question No. 4, nine hours.

Class 3—Cotton manufacturing, none.

Class 4—Woolen manufacturing, none.

Class 5—Woodworking. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
87	5 -hp	Single	4,764
88	5	"	283

Customer Number	Motor	Drive	Kw-hours
89	2½-hp	Single	503
90	5	"	250
91	10	"	1,061
92	2½	"	1,004
93	12	"	12,855
94	10	"	6,885
95	7½	"	3,741
96	3	"	1,626
97	15	"	2,436
98	7½	"	862
99	5	"	100
100	15	"	1,611
101	2	"	641
102	2	"	615
103	2		
	4	Group	2,581
104	10	Single	2,098
105	2	"	536
106	3	"	603
107	2	"	185
108	7	"	191
109	5	"	1,763
110	2½	"	839
111	3	"	2,581
112	3	"	1,826
113	12	"	545
114	12	"	
115	5	"	1,453
116	1	"	169
117	2	"	565
118	20	"	6,784
119	20	"	4,917
120	2	"	136
121	5	"	2,700
122	3		
	5	Group	2,444
123	5	Single	494
124	10	"	2,519
125	5	"	859
126	5	"	2,007
127	5	"	2,020
128	5	"	562
129	3	"	44
130	5	"	25
131	2	"	449
132	3	"	
133	10	"	
134	15	"	

The following is the synopsis:

Horse-power	1	2	2½	3	4	5	7	7½	10	12	15	20
No. of motors	1	8	3	7	1	14	1	2	5	3	3	2

The total number of factories is 48, having 50 motors of 312 horse-power.

Of these, 46 are driven by single motors and two by motors applied to groups.

Total number of kw-hours, 30,498.

Answer to question No. 4, eight hours.

Class 6—Metal-working. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
135	12 -hp	Single	2,965
136	5	"	3,206
137	(3) 5		
	15	Group	6,324
	20		
138	2	Single	87
139	3	"	1,881
140	(2) 10	Group	8,431
141	3	Single	1,615
142	3	"	1,883
143	2½	"	2,174
144	25	"	11,584
145	1½	"	303
146	3	"	1,519
147	5	"	2,076
148	2	"	344
149	1½	"	239
150	1	"	272
151	1	"	454
152	7½		
	12	Group	4,868
153	2	Single	1,230
154	1½	"	368
155	5	"	2,654
156	15	"	9,633
157	2	"	1,165
158	3	"	317
159	1	"	839
160	1½	"	945
161	1	"	333
162	5	"	2,651
163	2	"	464
164	6	"	1,005
165	7	"	1,991
166	(3) 40	Group	18,420
167	1	Single	240
168	4	"	
169	2½	"	247
170	3	"	779
171	7½		
	10	Group	8,060
172	10	Single	4,893
173	5	"	2,067
174	1	"	125
175	1	"	220
176	3	"	2,111
177	2½	"	967
178	10	"	6,100
179	5	"	6,628
180	1	"	750
181	3	"	1,660
182	3	"	2,241
183	10	"	4,646
184	7½	"	3,583
185	5	"	3,801
186	2	"	980
187	7	"	5,050
188	2	"	
189	7	"	3,736
190	5	"	3,112

Customer Number	Motor	Drive	Kw-hours
191	1½-hp	Single	
192	1	"	524
193	2	"	2,030
194	3	"	259
195	3	"	3,053
196	1	"	233

The following is the synopsis:

Horse-power	1	1½	2	2½	3	4	5	6	7	7½	10	12	15	20	25	40
No. of motors	10	5	8	3	11	1	11	1	3	3	6	2	2	1	1	3

Sixty-two factories, having 71 motors of 461 horse-power. Of these, 57 are driven by single motors and four by motors applied to groups.

Total number of kw-hours, 160,130.

Answer to question No. 4, eight hours.

Class 7—Bookbinding. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
197	5 -hp	Single	867
198	2		
	10	Group	2,012
199	3	Single	2,189
200	2	"	329
201	10	"	18,959
202	5		
	20	Group	10,734
203	2	Single	95

The following is the synopsis:

Horse-power	2	3	5	10	20
No. of motors	3	1	2	2	1

Seven factories, having nine motors of 59 horse-power. Of these, five are driven by single motors and two by motors applied to groups.

Total number of kw-hours, 35,185.

Answer to question No. 4, ten hours.

Class 8—Paper-box manufacturing. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
204	7 -hp	Single	9,501
205	5	"	3,911
206	2½	"	2,175
207	1	"	1,740

The following is the synopsis:

Horse-power	1	2½	5	7
No. of motors	1	1	1	1

Four factories having four motors of 15 horse-power. These are all driven by single motors.

Total number of kw-hours, 17,327.

Answer to question No. 4, nine hours a day.

Class 9—Clothing manufacturing. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
208	3 -hp	Single	3,881
209	3	"	4,576
210	1	"	534
211	1½	"	1,336
212	2	"	186
213	1	"	1,123
214	1	"	1,222
215	2	"	2,110
216	1	"	1,379
217	(2) 1	Group	
218	1½	Single	970
219	1½	"	1,561
220	3	"	2,055
221	2	"	1,750
222	3	"	1,797
223	2	"	1,738
224	2½	"	1,739
225	1½	"	1,216
226	1½	"	789
227	2	"	2,134
228	3	"	2,301
229	3	"	2,438
230	5	"	5,205
231	2	"	1,136
232	1	"	1,214
233	1½	"	1,606
234	1	"	1,449
235	1	"	928
236	5	"	6,358
237	1	"	2,770
238	1½	"	1,624
239	1	"	1,347
240	2	"	1,069
241	1	"	2,081
242	2	"	1,445
243	1½	"	970
244	2	"	2,955
245	1	"	715
246	3	"	2,319
247	2	"	1,908
248	1	"	2,190
249	1½	"	1,737
250	2½	"	1,433
251	5	"	2 365
252	1	"	1,569
253	2½	"	1,858
254	2	"	113
255	1	"	1,525
256	1½	"	1,407
257	1½	"	1,416
258	1	"	415
259	1	"	481
260	3	"	3,653
261	1		
	3	Group	3,730
262	1½	Single	633
263	1½	"	1,101
264	1	"	2,133
265	1½	"	1,410
266	2	"	1,470

Customer Number	Motor	Drive	Kw-hours
267	1 -hp	Single	1,441
268	2	"	2,148
269	5		
	3	Group	1,450
270	1½	Single	1,303
271	1	"	1,173
272	1	"	1,065
273	1	"	1,045
274	1½		
	3	Group	3,444
275	10		
	15	Group	20,708
276	1	Single	1,067
277	3	"	2,098
278	2	"	1,774
279	1½	"	1,918
280	1	"	837
281	1	"	1,161
282	1½		
	3	Group	4,112
283	1	Single	1,680
284	1	"	1,217
285	3	"	801
286	1	"	1,837
287	1	"	1,310
288	1½	"	1,667
289	2½	"	1,357
290	3	"	94
291	1	"	1,155
292	1	"	1,960
293	1½	"	1,583
294	3	"	1,769
295	1½	"	2,591
296	1	"	46
297	1	"	1,352
298	1½	"	367
299	3	"	3,960
300	1	"	1,430
301	1½	"	1,936
302	1	"	1,464
303	1	"	325
304	1	"	1,987
305	1	"	1,013
306	1½	"	1,478
307	3	"	2,617
308	3	"	2,679
309	3	"	
310	5	"	2,718
311	2	"	1,365
312	2	"	1,543
313	3	"	1,399
314	1	"	614
315	1½	"	1,727
316	1	"	593
317	3	"	1,176
318	2	"	1,119
319	1½	"	775
320	2	"	709
321	1½	"	439
322	1	"	381

Customer Number	Motor	Drive	Kw-hours
323	3 -hp	Group	712
324	1	Single	329
325	2	"	1,069
326	3	"	1,972
327	1½	"	2,112
328	2½	"	1,188
329	2	"	23
330	1	"	77
331	1	"	167
332	3	"	290
333	1½	"	83
334	1	"	55
335	1½	"	139
336	1	"	197
337	2	"	1,204
338	3	"	614
339	5	"	2,331
340	1½	"	1,357
341	5	"	2,173
342	1		
	3	Group	1,040
343	1½	Single	2,014
344	(2) 8	Group	

The following is the synopsis:

Horse-power	1	1½	2	2½	3	5	8	10	15
No. of motors	49	32	21	5	27	7	2	1	1

The total number of factories is 137, having 145 motors of 309 horse-power. One hundred and twenty-nine are driven by single motors and eight by motors applied to groups.

Total number of kw-hours, 228,409.

Answer to question No. 4, nine hours.

Class 10—Candy manufacturing. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
345	2 -hp		
	1		
	1	Individual	4,335
	3		
	15		
346	2	Single	349
347	(2) 1/8		
	1/2	Individual	221
348	1½	Single	340
349	2		
	3	Group	2,524

The following is the synopsis.

Horse-power	1/8	1/2	1	2	3	15
No. of motors	2	1	2	3	2	1

The total number of factories is five, having 12 motors, 31 horse-power. Of these, two are driven by single motors, one by motors applied to groups and two by motors running individual machines.

Total number of kw-hours, 7,769.

Answer to question No. 4, nine hours.

Class 11—Laundries. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
350	2	Single	396
351	3	"	2,953
352	3	"	1,641
353	2	"	479
354	2	"	1,289

The following is the synopsis:

Horse-power	2	3
No. of motors	3	2

The total number of factories is five, having five motors, 12 horse-power. These are all driven by single motors. Kw-hours, 6,758.

Answer to question No. 4, nine hours.

Jewelry manufacturing. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
355	5 -hp	Single	5,764
356	1	"	
357	1/4		
	1/2	Individual	1,575
358	1	Single	
359	1 1/2	"	733
360	2	"	2,058
361	1	"	347
362	1 1/2	"	377
363	1/2	"	227
364	1	"	74

The following is the synopsis:

Horse-power	1/4	1/2	1	1 1/2	2	5
No. of motors	1	2	4	2	1	1

The total number of factories is 10, having 11 motors, 15 horse-power. Of these, nine are driven by single motors and one by motor applied to individual machine.

Total number of kw-hours, 11,155.

Answer to question No. 4, eight hours.

Opticians. Horse-power and motors are as follows:

Customer Number	Motor	Drive	Kw-hours
365	1 -hp	Single	772
366	1/2	"	749
367	1	"	194
368	2	"	917
369	1	"	1,106
370	1/2	"	38
371	3	"	1,295
372	1/2	"	1,043
373	1	"	870

Customer Number	Motor	Drive	Kw-hours
374	1 -hp	Single	243
375	4		
	2½	Group	5,933
376	2	Single	1,380

The following is the synopsis:

Horse-power	½	1	2	2½	3	4
No. of motors	3	5	2	1	1	1

The total number of factories is 12, having 13 motors of 20 horse-power. Of these, 11 are driven by single motors and one by motor applied to single group.

Total number of kw-hours, 14,540.

Answer to question No. 4, nine hours.

Answer to question No. 5, 15 to 20 per cent.

Answer to question No. 6, under metal-working, 150-hp steam engine replaced by 55-hp motor. A 15-hp steam engine replaced by 10-hp motor.

Under clothing manufacturing, 5-hp gas engine replaced by 5-hp motor.

Under woodworking, 5-hp gas engine replaced by 5-hp motor.

Under printing, an 8-hp steam engine replaced by 10-hp motor.

Answer to question No. 7, none.

Answer to question No. 9, 3,356.

Answer to question No. 10, 19 per cent.

Answer to question No. 11, 17 per cent increase over horse-power connected January 1, 1903. Thirty-three per cent increase in total load during the year.

Answer to question No. 12, both.

Answer to question No. 13, 10 cents per horse-power per hour, with a discount of 10 per cent to 40 per cent, according to the amount used. We also make a minimum charge of $2.00 per horse-power per month, based not on the horse-power of the motor but upon the maximum demand.

I believe this answers your committee's inquiries as fully as the data we have at hand enable us."

EXHIBIT C—CHICAGO, ILLINOIS

The figures from the Chicago report are given below. Inasmuch as the report was drawn by one of this committee, a large part of the suggestions and recommendations, with which the report is particularly replete, have been omitted here and have been incorporated elsewhere as part of the committee's report.

"Replying to the first four questions, we submit a list of forty customers, giving in tabulated form, first, the number of motors installed for each customer; second, the total horse-power capacity of motors installed for each customer; third, the average number of hours per day during which each factory runs; fourth, the annual consumption of electricity for power in kw-hours; fifth, the kind of motor drive, whether by an individual motor on each machine or by running a group of machines on each motor; and sixth, the former source of power. Where the power was furnished formerly by a

steam engine and transmitted by belts or rope drive to the machines we have indicated it by the word 'Steam.' Where the transmission was partly by motors and partly by belts or ropes we have indicated it by the term 'Steam and Electric.' Where the customers had started up for the first time on our service we have used the word 'Original,' and where our service has been substituted for gas engine we have indicated it by the words 'Gas Engine.'

Of the eleven classes of factories suggested in your letter we have omitted four; namely, cotton manufacturing, woolen manufacturing, clothing manufacturing and laundries. We do not know of any cotton or woolen mills here in Chicago, and, while we have motors used for clothing manufacturing and laundry work, they are smaller installations and the information on them would not therefore have a direct bearing on the subject, which we understand to be especially the larger installations of power in factories.

In addition to the classes which you mention, we have given instances under manufacturing plumbers' supplies, the grinding and preparing of grain for foods, the manufacturing of absorbent cottons and porous plasters, the preparing of wholesale grocers' supplies, and the handling and cleaning of feathers.

The list which we submit is as follows:

CLASSIFICATION

Customer's No.	No. of Motors	Total Hp	Hours Operated per Day	Yearly Kw-Hours	Kind of Drive	Former Source of Power
BOOT AND SHOE MANUFACTURING						
1	21	54	10	42,684	Group	35-hp gas eng.
PRINTING						
2	21	45	13	43.676	Individual	Steam
3	11	50	11	35,489	Group and ind.	"
4	31	38	12	26,904	Individual	"
5	31	165	12	88,681	"	"
6	69	137	13	98,642	"	"
7	105	834	15	419.489	"	"
8	15	341	15	276,962	"	Original
9	13	25	20	28,811	"	20-hp gas eng.
				1,018,654		
PRINTING AND BOOKBINDING						
10	49	196	10-20	136,616	Individual	Steam
WOODWORKING						
11	14	91	9	32,046	Individual	Steam
12	6	52½	10	41,021	"	50-hp gas eng.
13	1	30	10	44,623	Group	Steam
14	1.	30	10	33,891	"	"
				151,581		
METAL-WORKING						
15	21	160	10	32,840	Individual	Steam
16	22	400	10	205,625	"	Steam and elec.
17	6	28	10	6,324	Group and ind.	Steam

Customer's No.	No. of Motors	Total Hp	Hours Operated per Day	Yearly Kw-Hours	Kind of Drive	Former Source of Power
18	7	115	10	85,980	Group	Steam
19	10	130	18	166,221	"	"
20	7	65	10	23,536	Individual	Original
21	5	63	9	62,894	Group	Steam
22	3	22	8	8,786	"	"
23	6	50	12½	73,962	"	"
24	19	148	10	116,860	"	"
25	7	78	10	42,862	Individual	"
26	11	225	11	110,750	"	"
27	10	29	10	16,718	"	"
28	5	33	10	31,650	Group	"
	139	1,546		1,370,766		
Plumbers' Fittings, Marble, Etc.						
29	21	238	10	148,512	Individual	Steam
Paper and Tin-box Manufacturing						
30	47	124	10	82,650	Group and ind.	Steam and elec.
Candy Manufacturing						
31	10	65	10	33,366	Group and ind.	Steam
32	29	115	10	102,651	" " "	"
Breakfast Foods						
33	3	150	10	180,149	Group	Original
Stock Foods						
34	3	50	10	23,576	Individual	Original
Cotton Carding and Porous Plasters						
35	35	160	10	142,840	Group and ind.	Steam
Wholesale Groceries						
36	23	259	10	104,520	Group and ind.	Steam
37	8	131	10	53,360	" " "	"
38	4	39	10	22,146	" " "	"
Feather Factory						
39	1	40	10	29,360	Group	Original
40	1	35	10	28,643	"	Steam

The sixth question is practically answered in the schedule. In a great many cases the electric motors were installed when the customer moved to a new building and the electrical installation represents a larger plant than the old steam plant. We therefore can not get a very close comparison between the motors required and the steam power employed to do the same work.

In the examples given in the schedule you will note that in the majority of cases the motors have been substituted for one or more steam engines. The reason for this is the fact that these installations are nearly all larger sized installations. On our smaller power installations we have a great many examples where gas engines have been supplanted by electric motors and central-station service. We have just made up a list of 130 customers, taken at random from our books, who have formerly used gas engines, but who

have thrown them out and substituted electric motors supplied with current from our central-station supply.

Referring to the ninth, ten and eleventh questions, we respectfully submit the following report of the Edison and Commonwealth companies in Chicago:

The motors connected to the Edison service January 3, 1903, are as follows:

Low-tension, direct-current,	general power,		14194.4	hp
	elevator	"	14225.5	"
alt. "	general	"	157.6	"
	elevator	"	10	"
500-volt power,	general	"	587.2	"
	elevator	"	559.5	"
This gives us a total of			29734.2	"

connected to the Edison lines January 3, 1903.

During the year from January 3, 1903, to January 2, 1904, the net increase in connected power load was 6211.6 horse-power; in other words, the increase on the Edison lines amounted to 21 per cent for the year.

The motors connected to the Commonwealth Electric Company's service January 3, 1903, are as follows:

Low-tension, direct-current	motors	for	general power,	1525.3	hp
" "	"	"	elevator "	355.5	"
alt. "	"	"	general "	3188.5	"
" "	"	"	elevator "	211.5	"
500-volt power	"	"	general "	391.	"
" " "	"	"	elevator "	62.5	"

This gives us a total of 5734.3 horse-power in motors connected to the Commonwealth service January 3, 1903.

During the year from January 3, 1903, to January 2, 1904, the increase in connected load was 2558.9 horse-power, or about 44.6 per cent on the Commonwealth lines.

Taking the Edison and Commonwealth companies together we find the total horse-power connected January 3, 1903, is 35468.5 horse-power. The net increase during the year of January 3, 1903, to January 2, 1904, is 8770.5 horse-power, or about 24.5 per cent.

Referring to the last question, as to our rates for power, I beg to inclose copies of our contracts for general power, also the special form for elevator service. These are the rates that are used both in the smaller installations and in the larger ones to which we have referred in the above schedule."

DISCUSSION

MR. BRINE: I want to hear from some of the members as to what supervision they have over the use of power that is sold for motor purposes. We recently had a case in Atlanta where we were negotiating to take on a factory of about 100 horse-power, and one of our solicitors told the proprietor of the factory that he could use the current for making light. I

turned that proposition down, and told him we could not allow it to be done.

MR. FERGUSON: If I may be permitted, I would say a few words on this subject. In my address last year as president I recommended that this committee on purchased electric power be appointed. I confess I am rather disappointed in the number of replies that have come in response to the inquiries of the committee. I think the reason is that the member companies do not appreciate the importance of the power business. In many of the larger cities the growth of the power business has been enormous; greater in proportion than that of the lighting business. In the large cities there are scores of installations of power, running from 100 to 1000 horse-power, and it seems to me that if the small companies took up this work they could make as great strides in proportion to the size of their cities.

I think many of you know, from the talks you have heard in these conventions in former years, of the success in large cities in cutting out the isolated plants. It is an old story now; I am not going to talk much upon it, but make the statement to show you what can be done. We have on our circuits at the present time in Chicago nine-tenths of the office buildings in that city. It is also safe to say that we have, not a part, but all, the club buildings in Chicago; and in nearly every case this business has been obtained only by taking out isolated plants. This applies to the Chicago Club, the Chicago Athletic Club, and the Union League Club. All these clubs have been operating plants for about ten years, but we now have all that business on our own station. I offer this to show you what can be done. If we can do that in the case of clubs and office buildings there is no reason why we can not do it in the case of factories. What I was after in making the recommendation for the appointment of this committee was not to have a report on the use of small motors, but a report of the success in getting big business, big factories, the class you would least expect to get. It is well known that the best engineers in the country recommend electrical transmission for factory work. As illustrations, we can point to the Deering Harvester Works in Chicago, the Chicago and Northwestern Railway shops, and a number of other

installations of this kind. It happens that in these two particular cases they are beyond the reach of the central-station system, being in the outskirts of the city, and are operated by isolated plants. That does not interfere at all with our arguments. If electrical transmission is the proper thing it comes down to a question of whether the central station can handle the business or allow the isolated plant to come in.

In an effort to obtain this business there is one thing that the solicitors forget to consider, which is also omitted from the report on this subject, and that is the question of load factor. The load factor where single or individual motors are used is 25 per cent, based on the running time of the factory. In places where group driving is used it ranges from 25 per cent to 50 per cent. When a solicitor goes in to see a customer and gives him a price per hp-hour, the proprietor immediately takes that price and multiplies it by the maximum horse-power of his plant and the number of hours it operates, and says he can not afford it. The solicitor is not smart enough to divide it by four and say that is really the price. I will give you a few illustrations of the value of electric power as against hand power, and in order that I may quote the figures correctly I will ask you to allow me to read them from a memorandum I have made.

We have on our lines a factory, at Twenty-fifth street and Armour avenue, for the manufacture of porous plasters and absorbent cotton. This factory has two five-hp motors, each of which will operate a line of forty sewing machines. The manager of the factory tells me that a girl can do double the amount of work where the sewing machine is run by motor that can be obtained from her if she runs the sewing machine by a treadle. In other words, electrical power doubles the amount done by each girl employed. The pay of these girls runs from $8.00 to $9.00 per week, or from 15 cents to 20 cents per hour. The average load on these motors is about four horse-power, so that the average total cost of running the motors is from 18 to 20 cents per hour, allowing liberally for the loss of efficiency in motors and figuring the cost of current at 4.5 cents per kw-hour. This would make the cost of current for each sewing machine half a cent per hour. From this we can see that the expenditure of half

a cent an hour has effected a saving of an expenditure of 15 to 20 cents per hour for manual labor, the ratio in favor of electrical power being as one to thirty.

Let us take another example: The Corbett Railway Printing Company has now been using our power for about two years in the Brock and Rankin building. It formerly used steam power furnished by the owner of the building. Mr. Corbett tells me that the old steam-power installation enabled him by using different-sized pulleys to vary the speed on his presses over a range of four speeds. The present installation gives him the choice of any speed whatever over a range of about 300 per cent. This difference corresponds to the difference made in most printing offices by the substitution of electric drive for the old system of steam engines with belts and pulleys. The Corbett Printing Company figures that it gets eight per cent larger output for the same labor by means of this greater flexibility in speed, since it is now enabled to use in each case just as high speed as is practicable for the work that is being done.

Assuming that the pay of a printer is 50 cents per hour, we should have a saving of four cents an hour on each press, or about 35 cents per day. The ordinary size of motor used on these presses runs from 1.5-hp up to 7.5-hp, the average being about three-hp. The average cost of power in this particular establishment runs $2.57 per month per horse-power connected. Figuring twenty-six days per month we should have about 10 cents per day, or for three horse-power, 30 cents per day; in other words, if steam power were furnished absolutely free, without any cost whatever, it would still pay the printer to buy his power from the central-station company at regular rates, and he would save money by doing so.

Another example is the Chicago Candy Company, at the southeast corner of Fulton and Sangamon streets. This company formerly operated an isolated plant, getting its power from a steam engine. About a year ago we installed ten motors having a total capacity of 65 horse-power. The steam engine was shut down, and since that time the power has been furnished from these motors operated by the Edison central-station current. Mr. E. K. Corle, the manager, states that they are more than satisfied with the change. Before

the motors were installed the power account was $600 per month. Since the motors have been installed the bills for Edison service have been about $125 per month and the total account has been $285, including the salary of an engineer to run a low-pressure boiler for cooking the candy. In other words, there has been a saving of over $300 per month by the adoption of Edison power.

If every company in the association would agree to it that during the coming year no factory should start up within the limits of their lines without first having the merits of electric motors driven by central-station service fully explained to the owners, the result would be an enormous stride onward in this branch of the business. Every station should make it a point during the coming year to employ men fully posted in this line of work; or if they can not find such men they should employ bright men of good mechanical ability and give them the opportunity to obtain the necessary information, so that these men in their turn may educate the public.

The subject of electrical power is one that is but very little understood by the vast majority of users, and until the power user has been fully informed as to the merits of using electrical power and the advantages to be derived therefrom, it is useless to expect him to discard the steam engine and the old methods to which he has been accustomed for so many years.

Mr. Arthur Williams: With Mr. Ferguson and the committee, I regret that a larger percentage of replies could not have been received to the questions asked by the committee. I do not think, however, that this small percentage indicates any lack of interest in this subject on the part of the members, but, as in New York, a lack of information necessary to schedule the answers to the questions that the committee prepared. The schedule required a great deal of work on the part of our statistician and the results were not in my possession until two days before leaving for the convention. The report was lost and I should have telegraphed for the figures had I known earlier that the paper was not in my possession. The results covered fourteen classes of power service, taking into account the daily use per horsepower installed. The averages vary from 20 to 70 per cent

in the usual nine or ten-hour period of daily work. I shall be glad to incorporate these figures in this report if it be the wish of the association.

Mr. Ferguson drew attention to a very important point in selling power—the tendency of our competitors to take the rated capacity of the motor, multiply it by the number of hours of daily operation, then by the cost per horse-power, claiming that the result is the cost of electric service. From an electrical standpoint, that is absurd. Only 20 to 70 per cent of the capacity, depending upon the class of work, should be taken. It was found in a recent test that about 50 per cent of the power was consumed in shafting and belting, and that result is not unusual. While the percentage varies from 20 to 70 per cent as the average, I have not the slightest doubt but that 50 per cent of the power expended in New York city is for merely driving the shafting and belting. The solicitor should have schedules and examples at his fingers' ends when talking on behalf of electric motors. The incidental advantages of electric-power service are very great. In the Government Printing Office at Washington the sick list was reduced 55 per cent by the substitution of individual electric motors and the elimination of shafting and belting, the attendant noise and vibration of which seemed to wear on the nerves of men as well as of women.

The cost of elevator service on our lines averages $18 per horse-power annually, ranging from $12 to $25. The general power service will probably average between $40 and $60 annually; and the cost of coal delivered at the doors of the boilers will in itself average $30 to $35 annually where coal is $3.50 per ton, to which must be added the cost of labor, supplies, interest and depreciation.

One of the most interesting of recent power developments is that at Montreal, instituted by Mr. Gossler, and I think we should ask him to give us a description of the Montreal methods.

Mr. Gossler: In reply to Mr. Williams' inquiry I will say that I notice the statement made in the report that there are two ways to reach the customer; first, reduce the rates until they are so low as to be attractive, with the alternative of educating the customer. I regret that the committee has overlooked or ignored the possibility of selling power on a

limited basis; that is, when it does not have to be supplied at the time of peak load. I have suggested that possibility on several occasions and have generally been met with the statement that it could not be done, especially in large manufacturing establishments. The best answer I can make to this is that it has been done, and is being done, and at the present time the Montreal company has connected to its lines power—not nominal rating of motors, but actual power—supplied on the limited basis of about 7500 horse-power, among the users being the Dominion Cotton Mills, to which we are under contract to supply 3500 horse-power and which has an average load of 3000 horse-power. They do not use power from four to six o'clock in the afternoon from the 15th of September to the 15th of March. At the same time, the number of factory hours of 3000 per annum is not decreased. They accomplish this by reducing the time for luncheon, starting fifteen minutes earlier each day and operating until four o'clock on Saturdays. In consequence of this arrangement we have obtained a power load in December at the time of our heaviest lighting load. I think that last December, on several days during the time just preceding Christmas, our power load from seven o'clock in the morning until six o'clock in the evening was about 90 per cent of the maximum demand. In the last six weeks the average power load from seven in the morning until six at night has been 85 per cent of the maximum demand. We have numerous contracts that require that at least part of the power shall be discontinued during the time of peak load; also contracts requiring power only from seven o'clock at night until seven o'clock in the morning—such as pumping stations and operating printing presses. We have had an all-day average load of 75 per cent of the maximum load.

CHARLES B. BURLEIGH (Boston): It occurred to me when reading over the report of the committee on purchased electric power in factories that the central-station people do not appear to appreciate the importance of this subject, from the fact that 462 inquiries were sent out and only 61 replies received.

The census report of 1902 shows that the yearly income derived from the sale of electric current by central stations amounts to something over $6,000,000 per year, and but $70,000 of this is received for the sale of current for stationary motors, or a little over one per cent.

I have made numerous notes, but on account of the limited time shall be obliged to discard them. The last gentleman that spoke practically covered the point that I want to make, which is that it is my impression that the central-station people do not fully appreciate the desirability of having as nearly a full all-day load-curve as possible, thus making their earnings a larger percentage on the original investment. When you first started in business you did municipal lighting four hours out of the twenty-four. You then looked around to get commercial arc lighting and increased your load-curve by two hours and found that you were earning an interest on your investment six hours a day; but your interest and depreciation were going on twenty-four hours a day, and you began to look around to see how you could increase your earning capacity still further. The electric railroad offered the easiest means to some of you and you took advantage of it and increased your load-curve, as per the report of the committee on progress, about six hours, but increased with a variable load and found it necessary to increase your investment to meet the conditions; that is, you did not increase your earning capacity in proportion to your increase in investment. Of course some of you had no facilities for increasing your earning capacity in this manner. It is, without question, extremely desirable for you to increase your revenue with as little increase of investment as possible.

Now, how can you best do this? The stationary motor will increase your load-curve to ten hours, anyway, and in some cases even more; electric heating and cooking will, unquestionably, also assist you. Most central stations wait for the power load to come to them, and the load that does come to them unsolicited is the load that they can least afford to run; it is a variable, intermittent load, for which they must necessarily charge a high price, because they must increase their investment to handle the maximum demand. You are looking for printing offices, machine shops, candy manufacturers, laundry machinery, *et cætera*, which are, on general principles, the poorest class of power business. These are the people who find it expensive to manufacture their own power, else they would not have come to you. The people who manufacture the power cheaply are, in nine cases out of ten, the people

to whom you can supply power cheaply, as they are the steady, all-day customers.

Why do you not get after the big fellow? He will give you ten hours' steady load, so that you can earn money on the investment that you make to meet the demand. This party says he can manufacture electricity as cheaply as you can, or more cheaply. He is a manufacturer of certain goods and his whole energies are, or should be, bent on producing his goods as cheaply as he can, and the power part of the cost is perhaps three to ten per cent of the cost of manufacture. The cost of power is but an incident to his business. Your business is making power. To make a living you manufacture it cheaper than anyone else, or you can not stay in the business. That being your business, your energies are all centred upon the one point of power production. Why do you not go to this manufacturer and show him that you are in a position to furnish power to him more cheaply than he can produce it—which you can unquestionably do? If he be a party using power ten hours per day, do not think that you have to get from him the same price per kw-hour as from the man who is using power to the same amount but three hours a day. You can afford to cut your price in two for the constant user and still make more profit than you can from the three-hour customer. You do not appear to appreciate this fact, but the prospective customer does, and you secure the business of the undesirable customer and lose that of the desirable one. It would pay each of you a handsome interest on the investment to carry, say, a 20-hp motor in stock at a cost of, say, not over \$500 or \$50 per year. Look over your territory and determine what customer you consider desirable. Go to him, tell him you would like to weigh his power with a view to verifying your judgment that you can furnish him with power more cheaply than he can produce it himself. Assure him that it shall not cost him anything. Install your motor and operate it as long as it is necessary for you to get his load-curve. This will not cost you a great deal. When you have secured his load-curve, superimpose it on your station load-curve and make him a rate in accordance with the cost of current at the point on your load-curve where his load appears. Be satisfied with a fair profit, and in nine cases out of ten

you will secure a good customer, and, by filling a depression in your load-curve, will assist in cutting down the cost of production on the rest of your load.

I am sorry that the limited time will not permit going into this subject more in detail, as it is one of great importance and worthy of most careful consideration.

MR. DUSMAN: I wish to say a word in defense of the report, which is largely statistical. Three years ago I became connected with a small company where there was one station wattmeter, 20 per cent of the customers on flat rate, 20 per cent on Edison meters, and the rest on any old type, with no records, no statistics, no financial records, or anything that would enable us to make up any report of consequence.

At the close of the convention last year I made the request that blanks asking for replies be sent to members in duplicate. If this committee, immediately after its appointment, had sent a form to all the companies, undoubtedly the companies would have taken the trouble to get the necessary information to fill out the forms more completely. Our company had no records of what was called for and consequently could not give it; but I am sure, from my experience, that if the committee had sent out its blanks earlier and in duplicate, it would have received more replies.

I make a motion that in future statistical blanks be furnished in duplicate and that all questions to be answered be printed on one side of the paper only, so as to give us an opportunity to distribute them among our different foremen, who must necessarily help to fill out the blanks; also that the blanks be printed in copying ink whenever practical.

(On motion, adjourned until half after two in the afternoon.)

FIFTH SESSION

President Edgar called the meeting to order promptly at half after two o'clock, and announced the first business to be the report of the committee on district heating, Mr. E. F. McCabe, chairman.

Mr. McCabe presented the following report:

REPORT OF COMMITTEE ON DISTRICT HEATING

National Electric Light Association:

MR. PRESIDENT AND GENTLEMEN: Your Committee on District Heating submits the following report:

It has been the effort of this committee to learn, if possible, the present condition of district heating, as an auxiliary to central-station lighting and power supply, from a physical and financial point of view, for the benefit of those companies now engaged in heating and those that have this subject under consideration.

A list of 24 questions was prepared and sent out, with an explanatory circular letter outlining the objects of the committee, and requesting replies in percentages, which it was thought would meet with the least objection from central-station managers.

Of 100 companies addressed, 52 made reply; 36 operating steam and 16 operating hot-water systems. The questions and replies have been tabulated and are herewith submitted.

A comparative schedule of 11 of the most pertinent questions and replies is submitted. From these data the committee makes its suggestions and recommendations.

The schedule gives a fair insight as to the relation of investment and income from heating systems as compared with lighting and power properties and revenues, and demonstrates that when once established they grow better each year. It also shows what proportion of fuel cost can be paid with heating income.

A comparison of the cost of steam coal and domestic coal would indicate that the central station had a tremendous advantage in first costs of operation, and it follows that if the same care is exercised in the sale of heat as in the sale of current, a combined property will show better returns on the money invested.

The committee recommends that a standard form of accounting be used by all companies operating heating systems, and submits herewith, for the approval of the associa-

tion, such a schedule. Further, the committee suggests that central-station managers give this point careful and immediate attention, so that they may derive by next year the benefits from the adoption of such a form.

It is the idea of the committee, in making this suggestion, that it would be well for operating companies to keep an account of this character (separate, if necessary, from their general accounting), so that for future reference comparisons could be made by proportions.

It is thought that this would be of value to many, in

COMPARATIVE STATEMENT REVENUE AND EXPENSES, SEASON OF 190 AND 190

Heating Department	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1. Revenue................									
2. Meter earnings........									
3. Contract earnings......									
4. Less rebates...........									
5. Net gross...............									
6.									
7. Operating expenses.....									
8. Fuel.....................									
9. Water....................									
10. Labor in boiler-room....									
11. Boiler repairs..........									
12. Repairs on mains and services..............									
13. Inspection meters, traps, etc.................									
14. Total operating expense.									
15. Net earnings...........									

comparing the work of their company with that of others, and it will enable the committee to formulate suggestions that will materially assist in bringing up the standing of district heating.

The replies to question No. 5, as follows, "What per cent of gross heating income do you charge to operating expenses?" are in many cases not to the point and indicate a lack of knowledge of this important feature, which is to be regretted. We therefore suggest that an effort be made by the management of companies operating heating plants to

COMPARATIVE SCHEDULE OF ELEVEN PERTINENT QUESTIONS AND REPLIES FROM FIFTY COMPANIES

No.	System	Year Established	Per Cent of Heating Investment to Electrical Inv.	Per Cent of Heat'g Income to Elec. Inc.	Heating Income Pays % of Fuel Bill: Heating Season	Heating Income Pays % of Fuel Bill: Entire Year	Method of Charges	Do You Control Charact'r of Inside Piping	Do You Insist on, and Charge for Cooling Coil Surface: Insist	Chg.	What is Charged to Depreciation	Price of Steam Coal per Ton	Price of Domestic Coal per Ton	Are you Satisfied with Investm't	Reports Received from States
1	Hot Water	1900	15	25	a 75	b 57.5	R.	No			None	S. $1 65	So. $3 50 H. 8 00	Yes	
2	"	1902	50	15	80	55	R.	Yes			2% and Repairs	M. run 2 15	4 50 7 50	Very	
3	Steam	1899	20	14.5	Pays all fuel and labor and leaves some net		M.	No	Yes	Yes	N. G.	Mixed, Hard & Soft 4 70	6 50 9 50	Yes	
4	Hot Water	1899	50	50		100	R.				10%	2 12	So. 3 00 and 5 00 H. 10 00	No	Alabama 1
5	Steam	1897	20	20	80	55	M. and A.	Yes	Yes	Yes	N. G.	2 25	4 00	Yes	Connecticut.. 1
6	"	1901	25	22	80	67	M. and A.	Yes	Yes	Yes	None	2 35	6 50	Yes	Colorado 1
7	"	1900	N. G.	N. G.	N. G.	N. G.	M.				N. G.	Mixed, Hard & Soft 4 50	So. 8 00 H. 10 00	Very	Georgia 1
8	"	1901	N. G.	N. G.	N. G.	N. G.	M.	Yes	Yes	Yes	None	Lp. 4 00	6 50	No	Indiana 5
9	Hot Water	1900	100	120	Pays all fuel used		R.	Yes			N. G.	M. run 1 57	2 50	Yes	Illinois...... 8
10	"	1900	2.04	5	50	25	R.	No			None	3 75	H. 8 50	No	Iowa........ 7
11	"	1902	N. G.	N. G.	N. G.	N. G.	R.	Yes			N. G.	1 70	So. 4 00 H. 8 00	Yes	Kentucky 1
12	Steam	1902	40	15	65	40	M.	Yes	Yes	Yes	7½%	3 00	7 00	No	Kansas...... 1
13	Hot Water	1900	15	15	Pays all fuel and more		A.	Yes			10%	2 00	7 00 10 00	Yes	Maryland.... 1
14	Steam	1903	N. G.	5		25	R. and M.	Yes	Yes	No	None	1 62	3 50	Yes	Missouri..... 1
15	Hot Water	1900	25	17	120	65	R.	Yes			2%	1 00	2 75	Yes	Massach'etts. 1
16	"	1903	33⅓	40	Pays all fuel and labor		R.	Yes			5%	2 40	4 50	Yes	Michigan.... 3
17	Steam	1900	20	6	N. G.	N. G.	R.	Yes	Yes	Yes	None	2 40	3 25	Very	Minnesota... 2
18	"	1902	10	18	100	66⅔	M. and R.	Yes	Yes	Yes	4%	1 70	2 50	Yes	New York... 2
19	"	1903	18	N. G.	N. G.	N. G.	M. and R.	Yes			N. G.	1 40	3 00	Yes	Ohio........ 4
20	"	1901	40	19	125	90	R.	No	Yes	Yes	6%	Nat. Gas 7c. M. S. 1 00	2 75	Yes	Pennsylv'nia 6
21	"	1901	263	N. G.	N. G.	N. G.	M.	No	Yes	No	None	1 17	1 50	Yes	North Dakota 1

N. G. = Not Given. R. = Square Ft. Radiation. M. = Meter. A. = Cubic Ft. Air Space. S. = Slack. M. = Mine Run. H. = Hard. So. = Soft.

COMPARATIVE SCHEDULE OF ELEVEN PERTINENT QUESTIONS AND REPLIES FROM FIFTY COMPANIES—*Continued*

22	Steam	1903	N. G.	N. G.	N. G.	N. G.	M.	Yes	No		None	N. G.	$7 00	Yes	Rhode Island 1
23	Hot Water	1901	100	100	N. G.	N. G.	R.	Yes			20%	$1 70	H. 10 00	Yes	Wisconsin . . . 2
24	Steam	1903	40	N. G.	N. G.	31.5	M. and A.	Yes	Yes	Yes	None	1 10	2 90	Yes	
25	"	1901	45	25	N. G.	N. G.	M.	No	Yes	Yes	None	2 00	4 50	Yes	
26	"	1903	N. G.	N. G.	N. G.	N. G.	A.	Partial	Yes		N. G.	1 50	3 50	Yes	
27	"	1896	10	14.3	100	68	M. and R.	Yes	Yes	Yes	6%	2 60	H. 11 00 So. 5 00	Very	
28	Hot Water	1901	15	15	70	50	R.	Yes			5%	4 00	H. 10 50 So. 6 00	Yes	
29	Steam	1895	20	25	87.5	63⅓	A.	No	Yes	Yes	5%	1 15	2 50	Yes	
30	"	1900	N. G.	8	66⅔	33⅓	M. and R	Yes	Yes	Yes	None	2 90	3 50	Yes	
31	"	1902	125	24	100	N. G.	A.	No	Yes	Yes	None	1 87	So. 3 50 H. 7 50	Yes	
32	"	1896	N. G.	N. G.	N. G.	N. G.	A.		Yes	Yes	N. G.	Lp. 4 00	6 50	Very	
33	"	1902	30	Feb. 32.7	over 100	N. G.	M.	Partial	Yes	Yes	None	2 46	4 25	Yes	
34	"	1888	25	33.5	N. G.	130	M. and R.	Yes	Yes	Yes	5%	90	2 25	Very	
35	"	1896	16⅔	33⅓	N. G.	88	A.	No	Yes	Yes	5%	1 75	Slack 2 00	Yes	
36	Hot Water	1901	12	5	50	33⅓	A. and R.	No			None	2 60	8 50	No	
37	Steam	1902	25	20	100	72	M. and R.	No	Yes	Yes	None	1 77	3 00 to 5 75	Yes	
38	"	1903	N. G.	N. G.	N. G.	N. G.	A				N. G.	N. G.	N. G.	Very	
39	"	1900	25	18	125	100	M. and R.	Yes	Yes	No	5%	1 40	2 00	Very	
40	"	1892	2	2	1	$\frac{6}{10}$	R.	Yes	No	No	None	3 40	So. 4 50 H. 7 50	Yes	
41	Hot Water	1900	N. G.	N. G.	N. G.	100	A.	Yes			5%	2 33	H. 9 50	No	
42	"	1899	N. G.	58.3	N. G.	62⅔	R.	Yes			10%	2 50	So. 6 00 H. 10 00	Yes	
43	Steam	1902	55.5	16⅔	N. G.	83	M. and A.	No	No		10%	2 25	6 00 to 4 25	Yes	
44	Hot Water	1901	100	50	150	100	R.	Yes			None	2 00	3 00 to 8 00	Yes	
45	"	1903	33⅓	12.5	50	12.5	R.	Yes			N. G.	3 00	So. 4 50 H. 7 50	Yes	
46	Steam	1903	20	N. G.	N. G.	N. G.	M.		Yes		N. G.	2 00	So. 4 00 H. 6 50	Yes	
47	"	1897	Live Steam	N. G.	N. G.	N. G.	M. and A.	No	Yes	Yes	5%	2 90	6 25	Yes	
48	"	1892	51.5	30	102	84	M.	Yes	Yes	No	4%	2 00	So. 3 00 to 5 00 H. 9 50	Yes	
49	"	1898	14	11.5	45	24	R.	No	No	Yes	5%	3 55	6 50	No	
50	"	1898	20	8⅓	N. G.	25	M. and R.	No	No	No	None	1 85	2 75	No	

N. G. = Not Given. R. = Square Ft. Radiation. M. = Meter. A. = Cubic Ft. Air Space. S. = Slack. M. = Mine Run. H. = Hard. So. = Soft.

determine, as closely as local conditions will permit, the cost of supplying heating service.

In many cases this can be arrived at only on an approximate basis, and for the benefit of those interested we suggest the following method for determining such costs :

Costs should be figured for each month separately.

$$A = \frac{\text{Total pounds coal burned}}{\text{Total output in kilowatts}} = \text{Pounds coal per kilowatt (heating months).}$$

$$B = \frac{\text{Total pounds coal burned (all non-heating months)}}{\text{Total output in kilowatts (" \quad " \quad ")}} = \text{Average pounds coal per kilowatt (non-heating months.)}$$

A—B = Total pounds coal per kilowatt chargeable to heating system.

Charges:

Coal, as above, together with proportionate amounts of water, labor in boiler-room and boiler repairs ; also total of all charges in direct connection with heating system.

It will be found that in many cases this basis will not give accurate results, on account of the varying load factors on each individual plant in summer and winter, and particularly in the cases of condensation plants ; a proper modification of the suggested basis may be safely left to the operating superintendent.

It is evident from the reports that, from a mechanical standpoint, the meter has not been fully perfected. This, no doubt, can be attributed to the short time that it has been on the market, and the consensus of comment indicates failures in mechanical detail rather than of the principle involved in its construction.

It is also desirable that some form of meter be devised for hot-water systems, judging from replies to question No. 7 by company No. 41, operating a hot-water system, which is as follows, "I believe meters would be the best. It would undoubtedly keep the doors and windows closed."

A set of standard rules and specifications for inside piping, if enforced, would solve many a problem as to the way in which pressures now required may be materially reduced. This is clearly shown by the replies to questions Nos. 10, 11, 12, 13, 14 and 15.

The committee can not too strongly urge that these questions and replies be given the most careful consideration, as here lies the bulk of the difficulties in the way of securing maximum benefit.

QUESTION I.

In what year was your heating plant established?

COMPANY	SYSTEM	
1	Hot Water	October, 1900.
2	Hot Water	1902-1903.
3	Steam	1899.
4	Hot Water	1899.
5	Steam	1897.
6	Steam	1901.
7	Steam	1900.
8	Steam	1901.
9	Hot Water	1900.
10	Hot Water	1900.
11	Hot Water	1902.
12	Steam	1902.
13	Hot Water	1900.
14	Steam	1903.
15	Hot Water	1900.
16	Hot Water	1903.
17	Steam	1900.
18	Steam	1902-1903.
19	Steam	1903.
20	Steam	1901.
21	Steam	1901.
22	Steam	1903.
23	Hot Water	1901.
24	Steam	1903.
25	Steam	1901.
26	Steam	1903.
27	Steam	1896.
28	Hot Water	1901.
29	Steam	1895.
30	Steam	1900.
31	Steam	1902.
32	Steam	1896.
33	Steam	1902.
34	Steam	1888.
35	Steam	1896.
36	Hot Water	1900.
37	Steam	1902.
38	Steam	1903.
39	Steam	1900.
40	Steam	1892.
41	Hot Water	1900.
42	Hot Water	1899.
43	Steam	1902-1903.
44	Hot Water	1901.

COMPANY	SYSTEM	
45	Hot Water	1903. (Schott's Balanced-column Hot-water System.)
46	Steam	1903.
47	Steam	1897.
48	Steam	1892.
49	Steam	1898.
50	Steam	1898.
51	Steam	1902.
52	Steam	Our heating plant was originally established in 1889. In the summer of 1900 it was entirely rebuilt, using the American District Heating Company's apparatus and system throughout.

QUESTION 2.

What is the proportion of your gross investment in heating plant to your gross investment in electric plant?

1	Hot Water	15 per cent.
2	Hot Water	50 per cent or one-third total.
3	Steam	20 per cent.
4	Hot Water	50 per cent or one-third total.
5	Steam	20 per cent.
6	Steam	25 per cent.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	100 per cent or one-half total.
10	Hot Water	2 per cent total.
11	Hot Water	Not given.
12	Steam	40 per cent.
13	Hot Water	15 per cent.
14	Steam	Not given.
15	Hot Water	25 per cent electric plant. 5 per cent entire property.
16	Hot Water	33 1-3 per cent.
17	Steam	20 per cent.
18	Steam	10 per cent.
19	Steam	18 per cent or 15 per cent total.
20	Steam	40 per cent.
21	Steam	263 per cent.
22	Steam	Not given.
23	Hot Water	100 per cent or one-half total.
24	Steam	40 per cent.
25	Steam	$5,000 less than one-half.
26	Steam	Not given.
27	Steam	10 per cent.
28	Hot Water	15 per cent.
29	Steam	One-fifth.
30	Steam	Figures for this not available.
31	Steam	Heating plant 12.5 per cent of electric plant.
32	Steam	Our heating system is incidental to our electric

COMPANY	SYSTEM	
		light plant. Our entire steam heating has cost us about $25,000.
33	Steam	30 per cent.
34	Steam	Heating plant 25 per cent, electric plant 75 per cent.
35	Steam	About one-sixth.
36	Hot Water	12 per cent of total.
37	Steam	25 per cent.
38	Steam	Not given.
39	Steam	One to four or 20 per cent.
40	Steam	2 per cent.
41	Hot Water	Not given.
42	Hot Water	Income from heat $7,000 yearly. Income from light $12,000 yearly.
43	Steam	Electric $45,000, heating $25,000.
44	Hot Water	About the same in each.
45	Hot Water	33 1-3 per cent.
46	Steam	About 20 per cent.
47	Steam	We do not do electric lighting.
48	Steam	Gross investment in heating plant is 51.5 per cent of gross investment in electrical plant.
49	Steam	About 14 per cent.
50	Steam	About one-fifth.
51	Steam	6 per cent.
52	Steam	Our gross investment in heating plant is 16.8 per cent of our gross investment in electric light and power plant, including electric distributing system.

Question 3.

What relation does your gross heating income bear to your gross electrical income?

1	Hot Water	25 per cent.
2	Hot Water	15 per cent.
3	Steam	14.5 per cent.
4	Hot Water	50 per cent.
5	Steam	20 per cent.
6	Steam	22 per cent.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	120 per cent or six-tenths of total.
10	Hot Water	5 per cent.
11	Hot Water	Not given.
12	Steam	15 per cent.
13	Hot Water	15 per cent.
14	Steam	5 per cent.
15	Hot Water	17 per cent.
16	Hot Water	40 per cent.
17	Steam	6 per cent.

COMPANY	SYSTEM	
18	Steam	18 per cent.
19	Steam	Not given.
20	Steam	19 per cent or 16 per cent gross investment.
21	Steam	Not given.
22	Steam	Not given.
23	Hot Water	100 per cent or one-half total.
24	Steam	Not given.
25	Steam	25 per cent.
26	Steam	Not given.
27	Steam	14.3 per cent.
28	Hot Water	15 per cent.
29	Steam	One-fourth.
30	Steam	Gross heating income is a little over 8 per cent of gross electrical income.
31	Steam	24 per cent.
32	Steam	Not given.
33	Steam	32.71 per cent for February, 1904.
34	Steam	Gross heating income 33.5 per cent; gross electric income 66.5 per cent for 1902.
35	Steam	About one-third.
36	Hot Water	One-twentieth.
37	Steam	20 per cent.
38	Steam	Not given.
39	Steam	At present one to five and one-half.
40	Steam	2 per cent plus.
41	Hot Water	20 per cent more for light than heating.
42	Hot Water	Income from heat, $7,000; light, $12,000 (yearly).
43	Steam	Electric light earnings about $18,000. Heating earnings about $3,000.
44	Hot Water	One-half.
45	Hot Water	One-eighth.
46	Steam	Not given.
47	Steam	Not given.
48	Steam	Gross heating income is 30 per cent of gross electric income.
49	Steam	About 11½ per cent.
50	Steam	Income of heat is about one-twelfth of electric.
51	Steam	October, 1903, to February, 1904, inclusive, 40 per cent.
52	Steam	Our gross heating is 7.76 per cent of our gross electrical income for lighting and power, not including income from hydraulic elevator service.

QUESTION 4.

What relation does your gross heating income bear to your fuel bill for all purposes (*a*) for the heating season, (*b*) for the entire year?

1	Hot Water	(*a*) 75 per cent, (*b*) 57½ per cent.

COMPANY	SYSTEM	
2	Hot Water	(*a*) 80 per cent, (*b*) 55 per cent.
3	Steam	Heat gross earnings pay all fuel and labor and leave some net.
4	Hot Water	(*a*) Not given, (*b*) 100 per cent.
5	Steam	(*a*) 80 per cent, (*b*) 55 per cent.
6	Steam	(*a*) 80 per cent, (*b*) 67 per cent.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	Income from heat will pay for all fuel used.
10	Hot Water	(*a*) 50 per cent, (*b*) 25 per cent.
11	Hot Water	Not given.
12	Steam	(*a*) 65 per cent, (*b*) 40 per cent.
13	Hot Water	Heat revenue is in excess of entire amount of fuel bill.
14	Steam	25 per cent, including fuel used for street railway.
15	Hot Water	(*a*) 120 per cent, (*b*) 65 per cent.
16	Hot Water	Income from heat will pay fuel and labor expense.
17	Steam	Not given.
18	Steam	(*a*) More than 100 per cent, (*b*) 66 2-3 per cent.
19	Steam	Not given.
20	Steam	(*a*) 125 per cent, (*b*) 90 per cent.
21	Steam	Not given.
22	Steam	Not given.
23	Hot Water	70 per cent of the fuel goes to the heating system.
24	Steam	(*a*) Not given, (*b*) 31½ per cent.
25	Steam	(*a*) During heating season the heat plant consumes about 60 per cent of our fuel.
26	Steam	Not given.
27	Steam	(*a*) 100 per cent, (*b*) 68 per cent.
28	Hot Water	(*a*) 70 per cent, (*b*) 50 per cent.
29	Steam	(*a*) Gross heating income, $35,000; (*b*) $35,000. Fuel bill $40,000 $55,000.
30	Steam	(*a*) Our gross heating income is about two-thirds of our fuel bill for the heating season, and (*b*) about one-third of the fuel bill for the entire year.
31	Steam	About equals coal bill for season of eight months.
32	Steam	We depend almost entirely on our exhaust steam. Occasionally in extreme cold weather we put in some live steam during the night and early morning when we have the smallest use for power.
33	Steam	It more than equals coal bill during heating season, but not entire year.
34	Steam	The gross heating income exceeded the fuel bill for entire year of 1902 by 30 per cent.
35	Steam	Fuel bill about $25,000, heat income about $22,000.
36	Hot Water	(*a*) Heating income 50 per cent of cost of fuel, (*b*) heating income 33 1-3 per cent of cost of fuel.
37	Steam	(*a*) Equal in heating season, (*b*) five-sevenths.

COMPANY	SYSTEM	
38	Steam	Not given.
39	Steam	(*a*) About as 20 to 16, (*b*) about equal.
40	Steam	(*a*) 1 per cent, (*b*) six-tenths per cent.
41	Hot Water	Fuel bill for entire year about equal to gross income for heating.
42	Hot Water	$11,000 fuel bill for year, $7,000 heat income for year.
43	Steam	Gross heating income, $3,000; coal bill for year, $3,600. We have spent about $50 per month for coal over and above the earnings from heating, so you see we have gone in a hole with our heating this winter, comparing the coal bills for last winter for lighting before we made the extension for heat.
44	Hot Water	(*a*) Fuel bill two-thirds of heating income, (*b*) heating income about covers fuel bill for entire year.
45	Hot Water	(*a*) One-half, (*b*) one-eighth.
46	Steam	The sales of steam heat for October, November, December, January and February of this season amounted to $4,155.74. We figure that for this period $1,000 worth of additional coal was used for the heating system. This statement is reasonably accurate, as we employ the average production of electric watts per pound of coal previous to the heating season for the production during the heating season. All additional coal used is charged to steam heat. If anything, this rule is unfair to the steam heat, as the efficiency of the plant is better during the time of highest production.
47	Steam	Not given.
48	Steam	(*a*) The gross heating income is 102 per cent of the fuel bill for the heating season; (*b*) 84 per cent for the entire year.
49	Steam	(*a*) About 45 per cent, (*b*) about 24 per cent.
50	Steam	Coal for the year 1902, $9,153, for all purposes. Income from heat, $3,314. Owing to advance in coal for 1903 our coal account was $13,100 for all purposes during that year.
51	Steam	October, 1903, to February, 1904, inclusive, 45 per cent.
52	Steam	Our gross heating income is 70.2 per cent of our fuel bill for all purposes at the stations from which we supply steam heat for the heating season, and 59.7 per cent for the entire year.

QUESTION 5.

What per cent of gross heating income do you charge to operating expense?

1	Hot Water	15 per cent.

COMPANY	SYSTEM	
2	Hot Water	Carry all expense together.
3	Steam	Not given.
4	Hot Water	Not given.
5	Steam	Not given.
6	Steam	10 per cent.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	Not given.
10	Hot Water	All of it. We believe that we do not make a profit on our heating business, on account of too much live steam used. We operate largely with water-power.
11	Hot Water	Not given.
12	Steam	Our operating expenses thus far do not amount to anything except extra coal used for live steam, and also meter inspection, but in order to cover depreciation, interest and repairs it will take the entire gross receipts.
13	Hot Water	50 per cent.
14	Steam	17.94 per cent.
15	Hot Water	We keep a detail of our operating expenses and therefore do not estimate heating separately.
16	Hot Water	Carry general expense account.
17	Steam	6 per cent.
18	Steam	33 1-3 per cent (about).
19	Steam	Not given.
20	Steam	20 per cent.
21	Steam	We can not answer this question correctly.
22	Steam	Not given.
23	Hot Water	50 per cent.
24	Steam	Have no permanent system.
25	Steam	We operate three plants—electric light, water-works and heat—in one building and under one roof. All are operated by the same set of men, but we estimate about one-fourth of operating expense at plant as chargeable to heat.
26	Steam	10 per cent.
27	Steam	30 per cent.
28	Hot Water	Not given.
29	Steam	Heating business is handled as electric-light earnings.
30	Steam	About 45 per cent.
31	Steam	None except labor of cleaning traps and inspection.
32	Steam	25 per cent.
33	Steam	None except actual expense in maintaining steam mains, meters and traps.
34	Steam	The per cent of gross heating income charged to operating expense was 65 per cent for 1902.

COMPANY	SYSTEM	
35	Steam	Not given.
36	Hot Water	All.
37	Steam	Not given.
38	Steam	Not given.
39	Steam	At present from 40 per cent to 50 per cent.
40	Steam	Not any.
41	Hot Water	About 60 per cent.
42	Hot Water	Don't know.
43	Steam	Not given.
44	Hot Water	Question not clear.
45	Hot Water	No definite data.
46	Steam	Not given.
47	Steam	About 25 per cent.
48	Steam	Operating expense, exclusive of interest and depreciation, is 80 per cent of gross heating income.
49	Steam	We credit operating expense with entire steam-heating income, spreading the receipts over the seven heating months. No additional labor is required in our boiler room, and the extra coal required to maintain heating pressure during hours of light electric load is charged to the operating expense of our electric station.
50	Steam	Use one-half live steam, balance exhaust. One-half of our gross receipts.
51	Steam	October, 1903, to February, 1904, inclusive, 40 per cent.
52	Steam	We make no division of this kind.

QUESTION 6.

Of what value, if any, have you found the heating business in the securing of new light and power business; also in retaining your light and power customers?

1	Hot Water	Of great value in retaining our light and power customers, as we have competition.
2	Hot Water	See no difference.
3	Steam	Our plant was put in to head off competition and to fortify our position.
4	Hot Water	None.
5	Steam	Refuse to furnish heat unless we get the light and power business.
6	Steam	No value.
7	Steam	Not given.
8	Steam	No value yet.
9	Hot Water	Not given.
10	Hot Water	Very slight aid
11	Hot Water	It has secured us customers for light we never could get otherwise

COMPANY	SYSTEM	
12	Steam	Thus far we have not found it of much value in obtaining new business.
13	Hot Water	None whatever.
14	Steam	Not in use long enough to determine.
15	Hot Water	No value. We control light, gas and railway.
16	Hot Water	Not given.
17	Steam	None.
18	Steam	We have found our heating system of considerable value in securing new light and power business, and of still greater value in retaining old light and power customers.
19	Steam	Of no considerable value.
20	Steam	Of value in securing light and power business in large buildings.
21	Steam	We think the main value of steam-heating plant lies in the fact that we are enabled to keep out isolated plants, with but few exceptions.
22	Steam	Not given.
23	Hot Water	Heat and light, also power, in good demand.
24	Steam	None so far.
25	Steam	None.
26	Steam	Not given.
27	Steam	This advantage has enabled us to shut down all isolated plants in our city.
28	Hot Water	Town too small for any possibility of isolated plants.
29	Steam	Not a great deal. Bulk of lighting business is small business; large not desirable.
30	Steam	Secures customers who would otherwise install isolated plants, such as office buildings, large department stores, etc., where boilers would be installed for heating apparatus and the same boilers be used for making steam for the operation of isolated plants.
31	Steam	None.
32	Steam	Not given.
33	Steam	Quite a help.
34	Steam	We consider the heating business a very good means of retaining and getting new power and light customers.
35	Steam	Help a little.
36	Hot Water	Has not been of any value.
37	Steam	Of some value, but unable to estimate.
38	Steam	Not given.
39	Steam	We have not noticed any connection or relation, one with the other.
40	Steam	Not any.
41	Hot Water	Not any.

COMPANY	SYSTEM	
42	Hot Water	But very little.
43	Steam	We have found it some value.
44	Hot Water	We have no opposition, therefore this does not apply.
45	Hot Water	Consumers equipped for heating are interested in the successful operation and maintenance of plant, inasmuch as they have hundreds of dollars invested and are at the mercy of heating company.
46	Steam	The heating system is of value for retaining light and power business.
47	Steam	Not given.
48	Steam	We have secured and retained several large buildings for light and power, which we would not otherwise have done.
49	Steam	It is open to debate whether the heating system has been of value in obtaining new customers. We have felt obliged to take on new day customers at extremely low rates in order to build up our day load, so that we might have sufficient exhaust steam to avoid the use of live steam. We have not yet reached the point where our day load is sufficient, while at night we have a surplus of exhaust.
50	Steam	None.
51	Steam	Not given.
52	Steam	The heating business is undoubtedly of great value in securing new lighting and power business, and in retaining light and power customers where the business is large enough to make it feasible to figure on putting in an isolated plant or where the business is favorable for installing block plants. This is shown by the fact that there is not a single plant of this kind in our heating district.

Question 7.

How do you charge for heat: flat rate, cubic feet of space heated, square feet of radiator service, or meter? From your experience, which system do you think best? Why?

1	Hot Water	Square feet radiation service.
2	Hot Water	Square feet radiation service.
3	Steam	Charge by meter. Would not consider any flat rate system as a safe and equitable way to charge.
4	Hot Water	20 cents per foot of radiation.
5	Steam	$2.00 to $4.50 per 1000 cubic feet of space heated; condensation meter, 35 cents per 1000 pounds: meter the only way, no heat wasted in this manner of charging.
6	Steam	By meter and cubic space heated. Moral effect of meter good, and best financially for us in severe

COMPANY	SYSTEM	
		winter weather. Mild winter, flat rates bring better returns.
7	Steam	Charge by meter. Rate, 60 cents per 1000 pounds.
8	Steam	Meter system. We think this method of charging best, because customer pays for what he uses.
9	Hot Water	15 cents per foot radiation.
10	Hot Water	We charge a flat rate of 25 cents per square foot of radiator service for heating season. We find it not satisfactory unless we oblige people to put in the full amount of radiation required.
11	Hot Water	Flat rate 15 cents per square foot of radiation.
12	Steam	We charge by meter only, which we think will be the most satisfactory system of charging, on account of customers being very much more economical when charged in this way.
13	Hot Water	We charge for the heating according to the amount of heat required to heat the premises properly; this being determined by the cubical contents, glass surface and exposed wall surface. We charge this amount regardless of the amount of radiation installed. They can install more or less, as they see fit.
14	Steam	Principally flat rate, based on square feet of radiation; have few meters also. Think flat rate better on account of moderate climate.
15	Hot Water	Square feet of radiation, based on the amount that should be used whether it is set or not.
16	Hot Water	Flat rate 17 cents per square foot radiation, October 1 to May 1. Extra charge for longer season.
17	Steam	Flat rate.
18	Steam	Up to this time we have charged for heat entirely on meter basis, our rates being $1.50 for the first 4000 pounds of condensation in a month and 50 cents for each 1000 pounds in excess of 4000 pounds, both amounts being subject to a discount of 10 per cent if paid at our office on or before the tenth day of the month. We are using the ordinary condensation meter manufactured and sold by the American District Steam Company. We have had considerable difficulty with these meters, as they clog up and are very easily rendered inaccurate. They require very frequent inspection and cleaning, in consequence. We have very recently provided also a schedule of flat rates. Considering the inaccuracy of meters and care required to keep them in order, our former opinions respecting the advisability of selling steam only on a meter basis are somewhat

COMPANY	SYSTEM	
		modified by experience. The ordinary isolated steam-heating plant as installed by the average plumber in this community, is not designed with reference to high efficiency in operation, and no uniform practice with respect to sizes of mains and risers, amount of radiation in proportion to cubical contents, reduction of exposures to a definite formula, obtains, therefore, meter bills for different consumers vary materially, producing considerable friction and discontent in the minds of the consumers, rendering it difficult to secure business at an established meter rate. We have just adopted an optional flat rate, as follows: For direct radiation in business buildings with economizing coils, 30 cents per square foot of radiation; for direct radiation in business buildings without economizing coils, also indirect radiation in business buildings with economizing coils, also direct radiation in dwellings with economizing coils, 35 cents per square foot of radiation. For indirect radiation in business buildings without economizing coils, also direct radiation in dwellings without economizing coils, also indirect radiation in dwellings with economizing coils, 40 cents per square foot of radiation. For indirect radiation in dwellings without economizing coils, 45 cents per square foot of radiation. For economizing coils, 20 cents per square foot of radiation. From each of the above a discount of 5 cents per square foot will be made for prompt payment. It is optional with the consumer to contract on the meter basis or flat rate basis, as he prefers.
19	Steam	By square foot of radiation for hot water. We prefer the meter for the district steam system.
20	Steam	25 cents per square foot radiation for maximum charge; large contracts less rate.
21	Steam	We charge for heat at a meter rate varying from 30 to 40 cents per 1000 pounds of water condensed from steam, after same has passed through the condensation coils, and find that this method of charging is entirely satisfactory from the standpoint of both the company and the consumer.
22	Steam	We charge by condensation meter only.
23	Hot Water	20 cents per square foot of radiation.
24	Steam	Meter when we can, 50 cents per 1000 pounds water condensed. Flat rate $3.00 per 1000 cubic feet, in the mercantile district only.

COMPANY	SYSTEM	
25	Steam	We are using meters, but they are not satisfactory; think we shall try square feet of radiation next season.
26	Steam	Cubic feet of space heated.
27	Steam	Flat on radiator, also meter. By all means, put all customers on meter.
28	Hot Water	17½ cents per square foot radiation; hot-water plant. Cubic-foot basis foolish.
29	Steam	Cubic feet of space heated. Flat rate best.
30	Steam	Our rates vary from 21 cents to 26 cents, net, per square foot of radiation per season. We have only a few meter customers, and are endeavoring to get all customers on a flat rate, as we have not been able to secure a meter that will give satisfactory results in registering the condensation.
31	Steam	We charge for cubic feet of space.
32	Steam	We charge 30 cents per 100 cubic feet for space heated for the entire year. We find we have to furnish heat for eight months.
33	Steam	By all means adopt meter system.
34	Steam	We charge for the square foot of radiating surface and also by meter. We consider the meter best method of making proper charge. In our experience, however, the operation of meters has not proven especially satisfactory, owing to the fact that their continuous operation can not be depended upon. We expect that improvements will be made in these in a short time, when this difficulty will be partially, if not completely, overcome.
35	Steam	$3.00 and $3.50 per 1000 cubic feet of space heated.
36	Hot Water	Charge per square foot of radiating surface for season. This system is satisfactory if we insist on customers installing enough radiation.
37	Steam	Square foot of radiator service and by meter. Meters on large customers, flat rate for small.
38	Steam	$2.75 and $3.00 per thousand cubic feet.
39	Steam	Our present practice is flat rate for square foot radiator service, but we expect to work into meter rate as soon as possible, as we think this system is the best, being most economical and equitable.
40	Steam	Square feet of radiation. No other system of charging would be practicable without the services of an expert on heating.
41	Hot Water	Cubic feet of space. I believe meters would be the best. It would undoubtedly keep the doors and windows shut.
42	Hot Water	20 cents per square foot radiation for the season, but shall advance it to 25 cents coming season.

COMPANY	SYSTEM	
43	Steam	Cubic feet of space heated. I think meter far the best.
44	Hot Water	Square feet of radiation required to heat building.
45	Hot Water	Flat rate square foot of radiator service. At present we have no meter for hot water.
46	Steam	Meter measure only. This I consider the only satisfactory way in the long run to sell anything, though the meters supplied for such purposes are not satisfactory instruments. The company making them has very poorly digested the conditions of use, and could have avoided many defects. These defects remedied, the meter ought to be fairly reliable.
47	Steam	Cubic feet of space heated, also by meter. Rate charged per thousand cubic feet for heating is as high as $12.00 for frame houses, exposed on all sides, and running down to $4.50 per thousand cubic feet for stores that are only exposed front and rear. These latter buildings must have a small glass exposure at each end.
48	Steam	By meter. We think meter system the best method of selling steam heat, because the company has practically no control over the steam used by customer, and without meters the waste would be excessive.
49	Steam	During the present season we have based our charges on the number of square feet of radiating surface in use (including uncovered piping), making flat rates for the heating season. About two years ago we were induced to install meters at a considerable expense, with the understanding that we could successfully charge for service according to the amount of water condensed. The meters failed signally, and we were obliged to return to a flat-rate system. The first installation of meters proved unsatisfactory, and had to be changed at our expense, requiring dash pots to obviate the noise occasioned by discharge. The new meters failed to record with sufficient accuracy, and have been entirely abandoned. We are advised, however, by the American District Steam Company that it is only necessary to install suitably proportioned economizing coils to make these meters operate successfully.
50	Steam	Flat rate. Would suggest meter. Charge so much per 1000 pounds of condensed water.
51	Steam	Flat rate, cubic-foot space, and meter.
52	Steam	Our regular rate of charge for heat is 50 cents per season per square foot of radiation for the first 1,000 square feet, 45 cents for the second 1,000

and 40 cents for all in excess of 2,000 square feet for radiators and uncovered pipe, and 30 cents per season per square foot of radiating surface in economizing coils. We have had a dozen meters installed for the last few months, for getting information. We find from this that our regular rate brings us in, on the average, less than 30 cents per thousand pounds of water condensed. We have therefore concluded that as a rule the meter system is the best system of charging, because it is conducive to economy on the part of the customer, and if fixed at the proper amount should make a saving to both the company and the consumer.

QUESTION 8.

Do you use regulators in connection with your meter?

1	Hot Water	Yes, Powers' Regulators.
2	Hot Water	Yes.
3	Steam	No.
4	Hot Water	No.
5	Steam	No.
6	Steam	No.
7	Steam	No.
8	Steam	No.
9	Hot Water	Would not heat without regulators.
10	Hot Water	No.
11	Hot Water	Use no meters, but use thermostats and regulators.
12	Steam	We advise regulators or reducing valves on all service pipes. We find this imperative where first-class service is desired. All systems of controlling steam from street supply are worthless without a good reducing valve.
13	Hot Water	We insist on all customers using Powers' Regulators.
14	Steam	No.
15	Hot Water	Do not use meters or regulators.
16	Hot Water	Yes. Powers' Regulators.
17	Steam	No.
18	Steam	We do not use regulators.
19	Steam	Not given.
20	Steam	No meters or regulators.
21	Steam	We operate the steam-heating system from exhaust steam exclusively and measure the water of condensation by the use of the simplex condensation meter, manufactured by the American District Steam Company, of Lockport, N. Y., and do not use pressure regulators in any installation.
22	Steam	We have never heard of a regulator to be used in connection with a condensation meter.

COMPANY	SYSTEM	
23	Hot Water	We use neither regulators nor meters.
24	Steam	No.
25	Steam	Some few of our customers have regulators. We do not furnish any or require them.
26	Steam	Not given.
27	Steam	No. Automatic valves.
28	Hot Water	Have no meters.
29	Steam	No.
30	Steam	We do not use any device for regulating the condensation before it reaches the meters, but endeavor to get a meter of sufficient size to handle any volume of water that might come from the system.
31	Steam	No.
32	Steam	No.
33	Steam	No.
34	Steam	No.
35	Steam	No. Only a few meters.
36	Hot Water	No.
37	Steam	No.
38	Steam	Not given.
39	Steam	No.
40	Steam	Not given.
41	Hot Water	Use regulators, but no meters.
42	Hot Water	No meters.
43	Steam	No.
44	Hot Water	We use thermostats, no meters.
45	Hot Water	We use Powers' Regulators.
46	Steam	No.
47	Steam	No.
48	Steam	No.
49	Steam	No.
50	Steam	Yes.
51	Steam	No.
52	Steam	Not given.

Question 9.

What comparison can you make relative to the cost of heating from your central station with the customer's former cost for fuel, care and maintenance?

1	Hot Water	25 per cent less, considering care and maintenance and wear and tear.
2	Hot Water	Only comparison we can make is with natural gas, which had practically no cost. Comparison not satisfactory.
3	Steam	We have cases where our steam costs 25 to 33 per cent less than fuel bill alone for private plant.
4	Hot Water	About equal.

COMPANY	SYSTEM	
5	Steam	About the same.
6	Steam	Cheaper for 1903-1904; 10 to 15 per cent higher other years.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	Not much difference.
10	Hot Water	Think our price is somewhat less than the customer's former cost, everything considered.
11	Hot Water	Believe we furnish heat as cheaply as our customers could do it themselves, if they furnished the same service as we.
12	Steam	At our rate of 40 cents per 1000 pounds of water condensed in the heating system we find that our customers having a vapor heating system or a Davis system of control, are heating cheaper from the street than they could do with their local boilers with anthracite at $6.59 per ton, gross.
13	Hot Water	We believe that the cost is somewhat higher by using our system.
14	Steam	Haven't formed a comparison yet.
15	Hot Water	About the same as customers' former cost for anthracite coal, without taking account of care and maintenance.
16	Hot Water	Our charge for heat approximates hard coal at $6.50 per ton.
17	Steam	If customers operated own steam plant our price of $3.50 per year per 1000 cubic feet is about same cost. Advantage to customer is in not having to handle coal and ashes; less dirt and annoyance; constant heat.
18	Steam	We have no data upon which to make a comparison of heating from our central station with the customers' former fuel cost. We find statements made by our customers on this point to be unreliable.
19	Steam	No definite information at hand.
20	Steam	Owing to customers using natural gas previously no fair comparison can be made.
21	Steam	The consumers save but little in purchasing steam from our company except in special cases, where we have to make a low rate for the purpose of keeping out isolated plants and obtaining profitable rates on these special contracts for lighting and power purposes.
22	Steam	As we are heating in a purely residence district it is impossible to figure the former cost for care and maintenance; our rates, so far as our judgment and observation have been able to compare them,

COMPANY	SYSTEM	
		run parallel with cost of coal for producing an equal amount of heat.
23	Hot Water	Cost of our heat about the same as fuel cost to customer.
24	Steam	Our charge about 25 per cent higher than customers' former cost.
25	Steam	Some claim it costs more, others admit it costs much less.
26	Steam	From 10 to 25 per cent higher. This is very hard for us to get at, for when customers use our heat they heat the entire building, but when they heat themselves with coal they only heat the apartments in actual use.
27	Steam	Not sure, but think we do it about 10 per cent less in most cases.
28	Hot Water	Usually central-station heat costs more.
29	Steam	Difficult to show comparison.
30	Steam	The basis of our charge for heating is fixed as nearly as possible by the cost of fuel and the care and maintenance of an isolated plant that is used for heating purposes only.
31	Steam	Some large contracts pay just the same. Smaller ones about 10 per cent more than for furnaces or private boilers.
32	Steam	We find that our rate just about equals cost of coal for heating same space.
33	Steam	Have made no comparison.
34	Steam	This depends on whether or not the customer would be required to employ additional labor to look after his own heating apparatus, and upon the size of the installation. In ordinary cases the service can be obtained from the central station at a nominal increase in cost.
35	Steam	No more cost, and they prefer it.
36	Hot Water	Think our service is possibly 10 per cent to 20 per cent cheaper.
37	Steam	Costs customer less.
38	Steam	Not given.
39	Steam	Heating from central station about 50 per cent greater than customers' former cost, fuel, etc., and yet our price for heating is less than elsewhere in the country.
40	Steam	About 15 per cent to 20 per cent cheaper.
41	Hot Water	For the same amount of heat and for the same length of time, I believe central-station heating is considerable cheaper, although the cost of central-station heating is somewhat higher than the former cost of fuel.

COMPANY	SYSTEM	
42	Hot Water	It is the universal opinion of our customers that we give them more heat for the money than they could get from hard coal at $10 per ton, and the luxury thrown in.
43	Steam	Don't know.
44	Hot Water	About the same where house was heated by furnace.
45	Hot Water	Very little, provided building is heated thoroughly, as we should heat it.
46	Steam	Central-station heating need not cost the consumer more than local heating.
47	Steam	About the same.
48	Steam	Steam customers are heating their premises at very little in excess of the former cost of fuel. Some are even heating for less.
49	Steam	The general expression of our customers is that the district heating costs somewhat more than their own installations, but that the additional convenience offsets this.
50	Steam	Hard proposition. Parties allow nothing for janitor, repairs, lifting of ashes, etc.; only figure actual cost of coal.
51	Steam	In some cases 40 per cent less, but generally about the same.
52	Steam	We have no exact figures in regard to this, but we are confident that the cost of heating from our service is less than from building plants, because of the ease with which we have obtained new business and held the old.

Question 10.

What supervision do you exercise over the inside piping of your customer, if any? Why?

1	Hot Water	Inspection of pipes and valves at opening of season or at all times necessary, and insist on covering of pipes or charging for the uncovered as radiation.
2	Hot Water	Our rules for piping must be followed or service will not be furnished.
3	Steam	We make suggestions that are generally followed.
4	Hot Water	Contract inclosed.
5	Steam	Piping done under our supervision. The better the piping the less pressure required.
6	Steam	Supervise all inside work.
7	Steam	Not given.
8	Steam	We see that customer is properly piped and that all condensation passes through the meter.
9	Hot Water	We install all radiation.
10	Hot Water	Only to avoid leakage.

COMPANY	SYSTEM	
		one hundred buildings on the system, one of which was piped so that it would not drain itself freely by gravity. You would have to raise the pressure considerably above that which is necessary to heat the other ninety-nine satisfactorily, in order to get this one system to work. For these reasons it is altogether important that the company should control or at least have supervision over the systems in the different buildings, and should be able to say whether they would connect a building to their mains or not.
31	Steam	None, except to clean steam traps from twice to three times per season.
32	Steam	Not given.
33	Steam	To enable us to carry less back pressure on engines and yet circulate steam to all customers.
34	Steam	We exercise no particular supervision over the inside piping of our customers, other than to see that the work is properly installed in regard to the sizes of mains and risers, and that the requisite amount of radiation is put in.
35	Steam	None; only compel them to keep it in order.
36	Hot Water	Only to see that there is no leaking and covering of pipes kept up.
37	Steam	None, only to require economizing coils where meter is wanted; as meter is more accurate.
38	Steam	Not given.
39	Steam	We keep a close supervision over the inside piping of the customer, and after a good deal of trouble with various plumbers, will not connect to a job that is imperfect, as we have found that they made us a good deal of trouble and bad results.
40	Steam	We use the vacuum system and require all piping and radiators to be kept tight, *i. e.*, without leaks.
41	Hot Water	We do all the piping. Work was not done to suit us when plumbers or steam fitters did it.
42	Hot Water	We insist on doing the work.
43	Steam	None, except we have our own valves inside of cellars so that we can cut same off at will, as the company owns the service pipe to that point.
44	Hot Water	Must be done according to plans and specifications furnished by us.
45	Hot Water	We have established rules that must be complied with in order to render satisfactory service and reduce leakage.
46	Steam	Not given.
47	Steam	We do not exercise any, but have learned from experience that old piping is to be avoided.

COMPANY	SYSTEM	
48	Steam	We have a set of rules governing certain features of piping where buildings are to be connected with our system. This is done to insure system working on least possible pressure and to avoid the use of steam without having same properly metered.
49	Steam	Our experience teaches us that periodic inspection should be given the customer's installation. We find that traps frequently stick, or become clogged and blow through; so-called automatic air valves fail to work, allowing pipes and radiators to become air-bound, causing complaint of low pressure; customers at times add radiation without due notice, etc., etc., so that we maintain an inspection department and make at least monthly investigation of all installations. Supervision should be given all new installations to see that piping is properly arranged and of ample size, etc., etc.
50	Steam	Must cover all pipe with pipe covering. Keeps exhaust steam from condensing in pipes.
51	Steam	Not given.
52	Steam	We require customers to pay for all uncovered pipe and to keep their traps working properly; the latter in order to prevent steam from blowing straight through into the sewer.

QUESTION 11.

To what extent does the condition of the inside pipe and radiation of your customer affect the pressure to be carried on the heating system?

1	Hot Water	Don't know.
2	Hot Water	Not given.
3	Steam	Radiation is figured ample to heat under three to five pounds pressure in weather 40 degrees below zero, Fahrenheit.
4	Hot Water	Not given.
5	Steam	See answer to question No. 10.
6	Steam	Does not affect the pressure of our system.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	Not given.
10	Hot Water	Not given.
11	Hot Water	Not given.
12	Steam	The condition of the inside piping affects the pressure carried on the street main as described in last part of the answer to question No. 10.
13	Hot Water	This refers to steam.
14	Steam	Has all to do with it; one bad job will injure a whole system.

COMPANY	SYSTEM	
15	Hot Water	To no extent. It does, however, affect the local circulation.
16	Hot Water	Very important to avoid carrying high pressure on your mains.
17	Steam	Should conditions be such that pipes are too small and many angles formed, such as found in old buildings, the effect of additional pressure is great; in our case we do not accept old buildings unless same are changed to meet our specifications.
18	Steam	The condition of the inside pipes and radiation does not affect the pressure we carry in our mains. We will not take on a customer whose radiation and pipes are too small, or not in accordance with our rules. We carry a maximum of three pounds pressure in our mains.
19	Steam	Not given.
20	Steam	Can't say.
21	Steam	Not given.
22	Steam	Nothing affects our pressure to be carried. We guarantee two pounds pressure in zero weather, and any job not in condition to give proper service at all times must be made so before we will connect with it.
23	Hot Water	Not given.
24	Steam	About four pounds back pressure.
25	Steam	None; but customer will notice promptly if anything is wrong with his pipes, for he will not get the heat.
26	Steam	Can't say, as we have made no tests yet.
27	Steam	We have had to refuse to heat many buildings on account of the high pressure required to get steam to all radiators.
28	Hot Water	Hot-water system.
29	Steam	Depends upon job; ordinarily very little.
30	Steam	See answer to question No. 10.
31	Steam	Not given.
32	Steam	With radiation closed on service pipes our loss in pressure is very little.
33	Steam	Considerable.
34	Steam	Not given.
35	Steam	We make them put in cooling coils, which saves heat.
36	Hot Water	Not given.
37	Steam	Small.
38	Steam	Not given.
39	Steam	We note that the greater the number of fittings and turns in the inside piping the greater the friction and the greater the pressure to be carried to do the work.

COMPANY	SYSTEM	
40	Steam	See answer to question No. 10.
41	Hot Water	Not given.
42	Hot Water	Poor piping is detrimental to the successful operation of the plant.
43	Steam	We have a drop of about three pounds at farthest end of line, which is about a quarter of a mile from station; in other words, between station and end of line. The back pressure carried to give satisfactory results is seven pounds.
44	Hot Water	If properly piped and equipped with regulators, to no extent.
45	Hot Water	Many leaks would necessitate the use of more fuel.
46	Steam	A customer is not accepted unless the inside system is satisfactory to us.
47	Steam	Where piping is old or poorly installed it takes more pressure for satisfactory service.
48	Steam	From two to ten pounds.
49	Steam	Materially, in our opinion. The natural tendency on the part of the customer is to economize in first cost of radiation, and to call on the steam company for higher pressures during cold weather. The system is frequently blamed, where in reality insufficient and improperly placed radiation is the cause of the trouble.
50	Steam	About 20 per cent.
51	Steam	Not given.
52	Steam	We contract to furnish two pounds pressure at the service and require the customer to have his piping and radiators so arranged that this will properly heat the building during the coldest weather.

Question 12.

Do you make a regular inspection of the customer's piping, traps, etc.?

1	Hot Water	Yes.
2	Hot Water	Yes.
3	Steam	Yes.
4	Hot Water	No.
5	Steam	Yes.
6	Steam	Yes.
7	Steam	Not given.
8	Steam	Yes.
9	Hot Water	Yes.
10	Hot Water	No.
11	Hot Water	Do not have any regular inspection dates or hours. We have access to all houses at any time.
12	Steam	We consider frequent inspection of customers' piping, etc., particularly the meters, essential.

COMPANY	SYSTEM	
13	Hot Water	We make at least a weekly inspection, and oftener if any complaints are made.
14	Steam	Yes.
15	Hot Water	Yes.
16	Hot Water	Yes.
17	Steam	No. Refer all inside trouble to steam fitters at customer's expense.
18	Steam	We make regular inspection of customers' traps and meters at least every two weeks.
19	Steam	Yes.
20	Steam	Yes.
21	Steam	Employ one man directly for the purpose of making daily inspections of meters, traps, piping, etc., and find that this is necessary to obtain the best results.
22	Steam	We make regular inspections of our traps and meters, but not of the rest of the installation unless the consumer requests it, when same is done and minor adjustments made by our "trouble man" without charge to customer.
23	Hot Water	Yes.
24	Steam	Yes; thus far, once a month.
25	Steam	Yes, once each week; more for the purpose of seeing that the meter is working than for any other purpose.
26	Steam	Yes.
27	Steam	Yes.
28	Hot Water	No.
29	Steam	Inspect traps and covering of pipe in basements regularly. We assume no responsibility as to sufficiency of radiation.
30	Steam	We keep a general supervision over all of the heating apparatus on the system and look after the traps pretty closely to see that they are working properly all the time.
31	Steam	Inspect traps three or four times per season.
32	Steam	We employ one man who makes regular inspections of all service traps, radiation, etc. He also makes whatever repairs may be necessary.
33	Steam	Yes, constantly; especially traps and meters.
34	Steam	We make regular inspections of customers' pipes, traps, etc., for which no charge is made unless repairs are used.
35	Steam	Yes, at beginning of season.
36	Hot Water	No.
37	Steam	We do of traps.
38	Steam	Not given.
39	Steam	We have just decided this year to make a regular inspection of all customers' traps, etc.

COMPANY	SYSTEM	
40	Steam	Yes.
41	Hot Water	Every six months.
42	Hot Water	No traps; water returns to plant.
43	Steam	We do, and recommend changes if needed.
44	Hot Water	Yes.
45	Hot Water	We do.
46	Steam	Not given.
47	Steam	Yes.
48	Steam	Yes; weekly.
49	Steam	Yes; monthly.
50	Steam	Yes.
51	Steam	Yes.
52	Steam	We make a yearly inspection of customers' piping, traps, etc., just before steam is turned on.

QUESTION 13.

Do you insist upon the use of economizing coils so placed as to extract the heat from the water of condensation, or is this left to the option of the customer?

1	Hot Water	We have the Yaryan hot-water system.
2	Hot Water	Not given.
3	Steam	We now insist on economy coils. We left it to the customer's option during the first year of operation.
4	Hot Water	Not given.
5	Steam	Yes.
6	Steam	All customers have economizing coils.
7	Steam	Not given.
8	Steam	I insist on economizing coils.
9	Hot Water	We heat by hot water.
10	Hot Water	Use hot-water system.
11	Hot Water	Our system is hot water and we use thermostats on every house, thus controlling the heat.
12	Steam	We strongly advise the use of economizing coils in the installations, and that the same be properly cased in sheet iron, with liberal ventilation so arranged that the heat used may be utilized in heating some portion of the building.
13	Hot Water	Refers to steam.
14	Steam	Yes, we insist upon their use.
15	Hot Water	Company does not use steam.
16	Hot Water	Ours is a hot-water plant—Yaryan.
17	Steam	Do insist upon economizing coils.
18	Steam	Up to this time we have insisted upon the use of economizing coils, treating them as indirect radiation. We are about to abandon this requirement.
19	Steam	Not given.
20	Steam	Charge higher rate if coils not used.

COMPANY	SYSTEM	
21	Steam	We insist upon the use of economizing coils in all installations.
22	Steam	We do not insist upon the use of economizing coils. Each customer pays for the steam used. He may install economizing coil and extract the heat of the water, and enjoy the ventilation it will give him or not, as he chooses.
23	Hot Water	Not given.
24	Steam	Insist that they be installed.
25	Steam	We tell them that it is a good thing for them to do while on meter basis. If we change our system we will compel them to do so.
26	Steam	Where the cooling coils can be used to an advantage we insist upon them being put in.
27	Steam	We insist on economizing coils.
28	Hot Water	Hot-water system. Such things not required.
29	Steam	Insist on it.
30	Steam	A coil of some kind should be used on all heating systems after the condensation passes the trap. We do not insist that this coil should be arranged as is commonly understood by an economizing coil. For instance, we frequently utilize the condensation after it has passed the trap for heating basements. This we usually do by putting an ordinary pipe coil on the wall and so arrange it that it will remain full of water all the time and overflow to the sewer. At other times we use the condensation for making hot water by means of an ordinary storage tank with a coil on the inside of it. Then, in other cases, we use an indirect cast-iron radiator so arranged that the water will pass through the entire coil and it will remain full of water. This we box up with a tin-lined wood box with a cold-air duct connected to the bottom and a warm-air duct taken from the top of the box and connected to a register on the first floor of the building.
31	Steam	We insist on the coils in every job.
32	Steam	Not given.
33	Steam	Yes.
34	Steam	We insist upon the use of economizing coils in every instance.
35	Steam	Yes.
36	Hot Water	Use hot-water system.
37	Steam	See answer No. 10.
38	Steam	Not given.
39	Steam	We insist upon the installation of economizing coils on premises of every customer.

COMPANY	SYSTEM	
40	Steam	See answer to question No. 10.
41	Hot Water	Not given.
42	Hot Water	Not given.
43	Steam	We do not.
44	Hot Water	As ours is a hot-water plant, above does not apply.
45	Hot Water	Not given.
46	Steam	Yes. The use of economizing coils is insisted upon.
47	Steam	We insist on economizing coils.
48	Steam	We will not connect unless economizers are installed.
49	Steam	Not at present, but we are considering this question and may decide to adopt the use of such economizer coils in connection with meters. We have a very few installations with economizing coils.
50	Steam	Left to customer.
51	Steam	We insist on use of economizing coils.
52	Steam	Yes.

QUESTION 14.

Do you charge for this class of radiation?

1	Hot Water	Not given.
2	Hot Water	Not given.
3	Steam	No.
4	Hot Water	Not given.
5	Steam	Yes.
6	Steam	Yes.
7	Steam	Not given.
8	Steam	No. Nothing extra. Meter takes condensation after passing through coils.
9	Hot Water	Not given.
10	Hot Water	Not given.
11	Hot Water	Not given.
12	Steam	The condensation meter used by us takes care of the economizing coils, as this is the customer's loss if the water is allowed to run away hot. We should advise charging for this class of radiation whether installed or not if selling heat at a flat rate, as boiling water leaving the building will take a large amount of heat with it, which the steam-heat company can not afford to lose.
13	Hot Water	Refers to steam.
14	Steam	No.
15	Hot Water	Not given.
16	Hot Water	Not given.
17	Steam	No. Figure amount of radiation for character of building; charge for full amount, deduct 15 per cent radiation and place 20 per cent cooling coils.
18	Steam	The condensation passes through the economizing

COMPANY	SYSTEM	
		coil and is weighed by the meter after it has passed the economizing coil.
19	Steam	Not given.
20	Steam	Not given.
21	Steam	We do not charge extra for radiation from these coils.
22	Steam	Not given.
23	Hot Water	We charge for risers and connections.
24	Steam	One-half regular price.
25	Steam	Yes.
26	Steam	No. Because we charge for all space heated by cubic feet of space heated.
27	Steam	Yes.
28	Hot Water	Have none.
29	Steam	Yes; cubic feet heated.
30	Steam	We charge for all kinds of radiation and exposed pipes. Any pipes that are covered with an approved covering are not charged for. We charge a uniform price for all kinds of radiation.
31	Steam	It is figured in as direct radiation at one-third actual surface.
32	Steam	Not given.
33	Steam	When supplying by meter, no. When flat rate, yes.
34	Steam	Yes.
35	Steam	Yes. Heat by space.
36	Hot Water	Not given.
37	Steam	No.
38	Steam	Not given.
39	Steam	We have not thus far charged for this class of radition.
40	Steam	See answer to question No. 10.
41	Hot Water	Not given.
42	Hot Water	Not given.
43	Steam	Not given.
44	Hot Water	Not given.
45	Hot Water	Not given.
46	Steam	Not given.
47	Steam	Yes.
48	Steam	No.
49	Steam	Yes.
50	Steam	No.
51	Steam	No.
52	Steam	Yes; charge is 30 cents per square foot of radiating surface.

QUESTION 15.

What ratio does this class of radiation bear to the direct?

1	Hot Water	Not given.

COMPANY	SYSTEM	
2	Hot Water	Not given.
3	Steam	One-sixth.
4	Hot Water	All direct.
5	Steam	About one-half.
6	Steam	17 per cent.
7	Steam	Not given.
8	Steam	Not given.
9	Hot Water	Not given.
10	Hot Water	Not given.
11	Hot Water	Not given.
12	Steam	Should consider that a fair proportion of radiation in the economy coil would be about 20 per cent of the entire radiation of the entire building. Charge for this radiation should be about 15 per cent of the rate on direct radiation.
13	Hot Water	Refers to steam.
14	Steam	Depends upon conditions.
15	Hot Water	Not given.
16	Hot Water	Not given.
17	Steam	20 per cent.
18	Steam	About 20 per cent.
19	Steam	Not given.
20	Steam	Not given.
21	Steam	Not given.
22	Steam	When installing we recommend about 20 per cent.
23	Hot Water	Not given.
24	Steam	Do not know.
25	Steam	About one-third less on a flat rate.
26	Steam	Not given.
27	Steam	About one-sixth.
28	Hot Water	Not given.
29	Steam	Ratio not considered.
30	Steam	See question No. 14.
31	Steam	One-fifth indirect.
32	Steam	Not given.
33	Steam	About one-fifth.
34	Steam	In charging the ratio is 15 for coil to 25 for direct radiation. In amount of radiation the coil service is 20 per cent of the total radiation connected.
35	Steam	One-sixth.
36	Hot Water	Not given.
37	Steam	One to eight.
38	Steam	Not given.
39	Steam	We have not made any examinations in the way of figures, but we have always considered that the heat from the cooling coils placed in the cellars was sufficient to keep the floors warm.

COMPANY	SYSTEM	
40	Steam	See answer to question No. 10.
41	Hot Water	Not given.
42	Hot Water	Not given.
43	Hot Water	Not given.
44	Steam	See answer to question No. 13.
45	Hot Water	Not given.
46	Steam	15 per cent to 20 per cent.
47	Steam	Just the same.
48	Steam	15 per cent.
49	Steam	One-fifth of total.
50	Steam	Very little.
51	Steam	20 per cent of direct.
52	Steam	We require surface in economizing coil to be one-fifth of that in radiation.

QUESTION 16.

Do you have any difficulty in securing or retaining customers for heating service?

1	Hot Water	None whatever.
2	Hot Water	No.
3	Steam	No.
4	Hot Water	No.
5	Steam	No; have all we can take care of.
6	Steam	No.
7	Steam	Not given.
8	Steam	No; during the last year we raised price and we lost one customer. They all think, however, that it costs them too much money.
9	Hot Water	No.
10	Hot Water	We have never lost any business and could double our business with very little trouble or expense.
11	Hot Water	We have not a dissatisfied customer on the plant.
12	Steam	Customers come on slowly, but we have never lost a customer unless he was moving off the line.
13	Hot Water	None whatever.
14	Steam	None.
15	Hot Water	Have not lost one customer since starting.
16	Hot Water	Have more than we want now.
17	Steam	No.
18	Steam	We have had considerable difficulty in securing customers for heating service on a meter basis at our present rates. Customers want to know what the cost will be before signing contract. We do not have any difficulty in retaining customers after they have been secured, provided they clearly understand what they may expect in the way of charges, before they sign the contract.

COMPANY	SYSTEM	
19	Steam	The most permanent and best customers we have.
20	Steam	Difficult to secure; never lose any.
21	Steam	We do not have any difficulty in securing or retaining customers for heating business.
22	Steam	We have not had time to lose any. We are informed that our customers are entirely satisfied with our rates and service, and we believe the prospects to be good for securing much new business next season.
23	Hot Water	No.
24	Steam	No.
25	Steam	No; can not furnish steam enough for all that want it, and the trouble is to keep them off the line.
26	Steam	None.
27	Steam	No. Can't take all we can get.
28	Hot Water	No.
29	Steam	We have advanced rates several times without loss of consumers.
30	Steam	We do not have much difficulty in securing customers and none whatever in retaining them. For instance, in the four years that this plant has been in operation we have never lost a customer except a few buildings that were burned down, and contracts for these will be received when the buildings are rebuilt.
31	Steam	None. Can not take all the business offered.
32	Steam	No.
33	Steam	No.
34	Steam	No.
35	Steam	No.
36	Hot Water	None whatever. Refuse much new business.
37	Steam	None in retaining them, but some trouble between landlord and tenant where tenant has lease, to get heating plant installed.
38	Steam	Not given.
39	Steam	We do not.
40	Steam	No; have reached our maximum capacity of exhaust steam.
41	Hot Water	No.
42	Hot Water	No; have more demand than we want to take on, as our heat load now far exceeds our exhaust load.
43	Steam	We do not.
44	Hot Water	No.
45	Hot Water	The only difficulty is in first cost for equipment.
46	Steam	No difficulty.
47	Steam	No.
48	Steam	No.

COMPANY	SYSTEM	
49	Steam	Have lost but one customer.
50	Steam	Yes; because we charge for heat during October and April.
51	Steam	Not answered.
52	Steam	Practically none.

Question 17.

Have you changed your method of construction since your plant was installed?

1	Hot Water	To some extent.
2	Hot Water	No.
3	Steam	No.
4	Hot Water	No.
5	Steam	No.
6	Steam	No.
7	Steam	Not given.
8	Steam	No.
9	Hot Water	No.
10	Hot Water	No.
11	Hot Water	No.
12	Steam	No.
13	Hot Water	Yes; we have put in the balance column.
14	Steam	Is a modern system; no changes.
15	Hot Water	Yes.
16	Hot Water	No.
17	Steam	No; have made no extensions. Would change method somewhat should we extend.
18	Steam	No.
19	Steam	Not given.
20	Steam	No; modern construction.
21	Steam	We operated on a live-steam basis during the season of 1901-1902, and in comparison with the season 1902-1903 we find that we made no mistake in using exhaust rather than live steam for heating purposes, as our results mentioned in answer to question No. 2 would certainly indicate.
22	Steam	No.
23	Hot Water	Not given.
24	Steam	No.
25	Steam	No.
26	Steam	No.
27	Steam	No.
28	Hot Water	No.
29	Steam	No.
30	Steam	We have not changed the method of construction, nor do we see any reason to do so.
31	Steam	No.

COMPANY	SYSTEM	
32	Steam	We have extended a little every year. Last fall we doubled our system. We have now about one mile of mains, heating 5,000,000 cubic feet of spa e.
33	Steam	No.
34	Steam	No.
35	Steam	No.
36	Hot Water	No.
37	Steam	No.
38	Steam	Not given.
39	Steam	No; not to any extent.
40	Steam	No.
41	Hot Water	No.
42	Hot Water	Only in the matter of service connection.
43	Steam	We have not.
44	Hot Water	In slight particulars.
45	Hot Water	Not materially.
46	Steam	Not given.
47	Steam	Not particularly.
48	Steam	Draining mains at frequent intervals and the making of service connections on top of mains. In any new additions to our mains we take advantage of any improvements that may have been adopted by the American District Steam Company.
49	Steam	No.
50	Steam	No.
51	Steam	No.
52	Steam	System was entirely rebuilt four years ago.

Question 18.

Do you think you could make more money if you had a plant of modern construction?

1	Hot Water	We have one of the best.
2	Hot Water	No; plant is up-to-date.
3	Steam	Our plant is modern.
4	Hot Water	Not given.
5	Steam	Yes.
6	Steam	No; is modern.
7	Steam	Not given.
8	Steam	We think it is modern.
9	Hot Water	No.
10	Hot Water	No.
11	Hot Water	We think we have a plant of modern construction.
12	Steam	We think our plant is of modern construction, as it has been built within two years; but we think that much better construction might be made with a little greater cost.
13	Hot Water	Our plant is absolutely modern.
14	Steam	Is modern.

COMPANY	SYSTEM	
15	Hot Water	It would be more satisfactory.
16	Hot Water	Not given.
17	Steam	No; not materially.
18	Steam	No.
19	Steam	Not given.
20	Steam	Not given.
21	Steam	Our steam-heating system is of modern construction.
22	Steam	Not given.
23	Hot Water	We have a modern plant.
24	Steam	Just installed.
25	Steam	We think this is modern. It certainly gives us no trouble.
26	Steam	Not given.
27	Steam	Yes; that is, large street mains.
28	Hot Water	We have a modern plant.
29	Steam	No; our plant is modern.
30	Steam	I feel quite sure our plant is an up-to-date one, at least in point of construction. Do not know of any way we could improve it.
31	Steam	Our plant is modern.
32	Steam	Not given.
33	Steam	We have modern construction.
34	Steam	No; we consider our plant to be fairly modern in construction. In any event, that recent extensions are up-to-date.
35	Steam	We have modern construction.
36	Hot Water	No.
37	Steam	We have a modern plant.
38	Steam	Our plant is modern; was installed last fall.
39	Steam	We think the more modern the better.
40	Steam	Yes.
41	Hot Water	No.
42	Hot Water	Don't know of anything any better.
43	Steam	We do not, as ours is up-to-date with a few exceptions.
44	Hot Water	Ours is modern.
45	Hot Water	Not given.
46	Steam	Not given.
47	Steam	Yes; we would install differently.
48	Steam	Not given.
49	Steam	Our plant is practically modern.
50	Steam	Yes.
51	Steam	Not given.
52	Steam	Not given.

QUESTION 19.

What do you charge off for depreciation?

1	Hot Water	We have charged off nothing for depreciation thus far.

COMPANY	SYSTEM	
2	Hot Water	After all expenses and repairs have been paid, then charge off two per cent on cost of plant.
3	Steam	Not given.
4	Hot Water	10 per cent.
5	Steam	Not given.
6	Steam	Nothing yet.
7	Steam	Not given.
8	Steam	We have not had our system in operation long enough to estimate amount to be charged off for depreciation. We think it will be very light.
9	Hot Water	Not given.
10	Hot Water	Nothing.
11	Hot Water	Not given.
12	Steam	We are of the opinion that the depreciation amounts to about 7.5 per cent.
13	Hot Water	10 per cent.
14	Steam	We have not decided yet.
15	Hot Water	Two per cent of capitalization of entire plant.
16	Hot Water	Five per cent.
17	Steam	Nothing.
18	Steam	We estimate depreciation at about four per cent of total construction cost.
19	Steam	Not given.
20	Steam	Six per cent.
21	Steam	We have not as yet charged anything off for depreciation except amount for repairs and renewals, which we charge off in operating expenses each month.
22	Steam	Not given.
23	Hot Water	20 per cent per annum.
24	Steam	Nothing yet.
25	Steam	Nothing but repairs.
26	Steam	Not given.
27	Steam	Six per cent.
28	Hot Water	Five per cent.
29	Steam	Five per cent.
30	Steam	We have no specified charge made for depreciation.
31	Steam	Nothing.
32	Steam	Not given.
33	Steam	Nothing yet.
34	Steam	Five per cent.
35	Steam	Five per cent.
36	Hot Water	Nothing.
37	Steam	Nothing.
38	Steam	Not given.
39	Steam	Five per cent.
40	Steam	Nothing.

COMPANY	SYSTEM	
41	Hot Water	Five per cent.
42	Hot Water	10 per cent.
43	Steam	10 per cent.
44	Hot Water	Nothing as yet.
45	Hot Water	Not given.
46	Steam	Not given.
47	Steam	About five per cent.
48	Steam	Four per cent.
49	Steam	Our general charge of seven per cent for depreciation on electrical property covers this. Our estimate of depreciation for steam system, alone, would be about five per cent.
50	Steam	Nothing.
51	Steam	Nothing up to present time.
52	Steam	We make no charge for depreciation.

QUESTION 20.

To what extent have repairs been necessary, due to actual wear and tear on the heating system, and not to accident?

1	Hot Water	Practically nothing.
2	Hot Water	Almost no expense.
3	Steam	None.
4	Hot Water	Not given.
5	Steam	No repairs necessary.
6	Steam	No repairs and no accidents.
7	Steam	Not given.
8	Steam	No repairs outside of boilers and meters.
9	Hot Water	None as yet.
10	Hot Water	Our only expense has been to replace tubes in a live-steam heater.
11	Hot Water	None.
12	Steam	We have had no repairs to make as yet. Have had no accidents, and the only trouble we have had has been due to surface water getting into the wood logs.
13	Hot Water	None due to wear and tear, but a great many to accidents.
14	Steam	Practically none.
15	Hot Water	$964.47 since July 1, 1903, because of defective mains; otherwise nothing.
16	Hot Water	None yet.
17	Steam	None.
18	Steam	Merely nominal.
19	Steam	We have made no repairs yet. This is our first year.
20	Steam	No repairs. Our only trouble has been from subdrains being poorly constructed in clay trench. Should have six inches of broken stone on bottom to keep drains open.

COMPANY	SYSTEM	
21	Steam	The repairs and renewals charged off in operating expenses during 1902-3 on boilers, engines, electrical apparatus, tools and implements, piping inside heating plant, mains and services in streets, meters and condensation coils in buildings, equal the amount of 10 per cent on the total investment. The repair and renewal account on boilers alone equals two per cent of the 10 per cent indicated, this fact being due to the boilers being old and requiring a considerable amount of repairs during the last two years.
22	Steam	Not given.
23	Hot Water	Not given.
24	Steam	None.
25	Steam	None.
26	Steam	None yet.
27	Steam	None.
28	Hot Water	One per cent.
29	Steam	Nothing to speak of.
30	Steam	The cost of repairs and maintaining the mains on this system has been very little.
31	Steam	None.
32	Steam	During our eight years' experience we have never had any serious leaks or trouble of any kind.
33	Steam	None.
34	Steam	About 2.5 per cent, including mains and service pipe.
35	Steam	None.
36	Hot Water	Our only repairs have been to repair flues in live steam heater.
37	Steam	Very small amount.
38	Steam	Not given.
39	Steam	Very small up to this time.
40	Steam	Our repairs have been more than normal on account of cheap and faulty construction of pipe line in 1892.
41	Hot Water	None.
42	Hot Water	None.
43	Steam	We have had to make no repairs since we started.
44	Hot Water	None.
45	Hot Water	Apparently none, with the exception of pipe lines outside of station.
46	Steam	No repairs as yet.
47	Steam	About one per cent of the cost.
48	Steam	Repairs have averaged about three-fourths of one per cent per annum.
49	Steam	None.
50	Steam	Very little.

COMPANY	SYSTEM	
51	Steam	None thus far.
52	Steam	Practically none.

QUESTION 21.

Do you return the water of condensation to the station for re-evaporation? If not, do you think it would be wise to do so?

1	Hot Water	
2	Hot Water	
3	Steam	No; we do not. It would not pay us to return the water.
4	Hot Water	
5	Steam	No; too much oil in the water.
6	Steam	No; we do not return the water of condensation, and think it would cost us more to do so than it is worth.
7	Steam	Not given.
8	Steam	We return condensation of mains to the plant.
9	Hot Water	
10	Hot Water	
11	Hot Water	
12	Steam	We do not return the water of condensation for re-evaporation, as it would cost us more than it is worth.
13	Hot Water	
14	Steam	No.
15	Hot Water	Since we use water-circulating system we return all water to the station and use our condensed water for boiler feed.
16	Hot Water	
17	Steam	No; trap in each building.
18	Steam	No. To safely return water of condensation would require a separate set of brass mains.
19	Steam	Not given.
20	Steam	No; grades prohibit it.
21	Steam	We do not return the water of condensation for re-evaporation, but the writer thinks that it was a serious mistake not to install return pipes when the steam mains were first installed. The advantages in returning the water to steam plant are: first, the water could be returned at a temperature considerably greater than 100 degrees Fahrenheit, which would help the economy in producing steam; second, we could save something in operating expenses, because of our company having to purchase water from the city on a meter basis at a rate of six cents per 1000 gallons; third, we should have the advantage of obtaining soft water to mix with the

COMPANY	SYSTEM	
		city water, thus reducing the formation of scale in the tubes.
22	Steam	We do not.
23	Hot Water	
24	Steam	No; not in our instance.
25	Steam	No; we do not return the water. It might pay if you could get a pipe to stand the service.
26	Steam	We do not; and we do not think it would be wise to do so in our case, as we could not unless using pumps to force it back to the plant.
27	Steam	No; it would not pay to pump it back.
28	Hot Water	
29	Steam	No; we do not, but think it would be wise to do so.
30	Steam	We do not return the condensation to the plant, but waste it all in the low places in the mains through a trap to the sewer, and in each building the condensation is thrown into the sewer. To undertake to return the water from the different buildings and the mains back to the plant would be a very expensive undertaking, and I am inclined to think it would be detrimental to the system, especially when you are using almost exclusively exhaust steam.
31	Steam	The condensation from five blocks of mains is returned to the station, but no condensation from radiation is utilized.
32	Steam	No; we waste our drips to the nearest surface drains at the point of radiation. We do not think it pays to return the condensation to the power-house.
33	Steam	No.
34	Steam	We do not consider that we should be anything ahead by returning the water of condensation to the station for re-evaporation, owing to the extra cost for installation and maintenance of the return pipe.
35	Steam	No; we have our own water, so do not value the same.
36	Hot Water	
37	Steam	We do not, nor do we think it would be wise to do so.
38	Steam	Not given.
39	Steam	We are not able to do this, but think it would be wise to do so where possible.
40	Steam	Yes.
41	Hot Water	
42	Hot Water	
43	Steam	We do not, and don't think it would be wise to do so.
44	Hot Water	
45	Hot Water	

COMPANY	SYSTEM	
46	Steam	No. I do not think it would pay to return the water of condensation to the station, as it would be of value for but two or three months of the year, having plenty of exhaust steam for feeding water the rest of the time.
47	Steam	Impracticable.
48	Steam	We do not return water of condensation, but think it would be profitable to do so when conditions are favorable.
49	Steam	No; cost of water is low, and the difficulty of returning it in our case would not justify the expense.
50	Steam	No; we do not. Think it would be wise to do so.
51	Steam	We do not return water. It would be an excellent idea to do so provided the expense of fitting up for same would not be too great.
52	Steam	We do not return water to station, and do not think the saving resulting from this would justify the additional investment required.

QUESTION 22.

What do you pay per ton (2240 pounds) for steam coal?

1	Hot Water	$1.65 per ton of 2000 pounds on siding at our plant.
2	Hot Water	$2.15 per ton of 2000 pounds for Indiana run-of-mine.
3	Steam	We pay $4.70 for a mixture of one-third soft and two-thirds hard coal screenings.
4	Hot Water	$2.00 to $2.25.
5	Steam	$2.25.
6	Steam	$2.35.
7	Steam	We pay $4.50 for a mixture of one-third Youghougheny screenings and two-thirds anthracite.
8	Steam	About $4.00 for Pocahontas this winter.
9	Hot Water	$1.57½ per ton of 2000 pounds delivered, run-of-mine bituminous.
10	Hot Water	Wilmington lump coal, $3.75.
11	Hot Water	$1.40 to $2.00 per ton.
12	Steam	Good steam coal is about $3.00 per ton.
13	Hot Water	$2.00.
14	Steam	$1.62½.
15	Hot Water	$1.00 per 2000 pounds.
16	Hot Water	$2.40 in coal shed.
17	Steam	$2.40.
18	Steam	$1.70 per gross ton for run-of-mine coal.
19	Steam	$1.40 for local steam coal per ton.
20	Steam	Use natural gas; seven cents per 1000 feet. Slack costs us $1.00.
21	Steam	We use run-of-mine lignite coal, which costs us $1.45, and slack lignite at 90 cents per ton delivered in the bins.

COMPANY	SYSTEM	
22	Steam	Not given.
23	Hot Water	$1.70.
24	Steam	$1.10.
25	Steam	$2.00.
26	Steam	$1.50 per ton for slack coal.
27	Steam	Not given.
28	Hot Water	$4.00.
29	Steam	$1.15 per ton of 2000 pounds.
30	Steam	Our coal costs us at the boilers $2.90 per ton of 2240 pounds.
31	Steam	$1.75 to $2.00 per 2000 pounds for run-of-mine coal.
32	Steam	$4.00 per 2240 pounds best bituminous coal in our boiler house.
33	Steam	$2.46.
34	Steam	About 90 cents gross ton delivered.
35	Steam	$1.75 per ton 2240 pounds slack coal.
36	Hot Water	$2.60 per ton of 2000 pounds for Illinois screenings.
37	Steam	$2.00 for run-of-mine, $1.55 for slack.
38	Steam	Not given.
39	Steam	$1.40.
40	Steam	Average $3.40.
41	Hot Water	$2.33.
42	Hot Water	$2.50.
43	Steam	$2.25 delivered.
44	Hot Water	$2.00.
45	Hot Water	$2.30 to $3.75.
46	Steam	Low grades of anthracite are used, at an average of $2.00 per ton.
47	Steam	About $2.85 to $2.90.
48	Steam	$2.00 per ton.
49	Steam	No. 1 buckwheat, $3.35 per gross ton delivered; pea coal, $3.75 per gross ton delivered.
50	Steam	$1.85 per 2000 pounds on track.
51	Steam	2000 pounds, $1.90 to $2.30.
52	Steam	$2.00.

Question 23.

What is the price of domestic coal used for heating purposes in your city?

1	Hot Water	Anthracite $8.00 per ton, bituminous $3.50 per ton.
2	Hot Water	Anthracite $7.50 per ton, Pgh. Dom. lump $4.50.
3	Steam	Anthracite $9.50, soft coal $6.50.
4	Hot Water	Hard coal $10, soft $3.00 to $5.00.
5	Steam	$4.00.
6	Steam	$6.50 per ton to non-employees of railroad company.
7	Steam	Bituminous $8.00, anthracite $10.
8	Steam	About $6.50.

COMPANY	SYSTEM	
9	Hot Water	$2.50 per ton.
10	Hot Water	Anthracite $8.50 ton of 2000 pounds.
11	Hot Water	$3.50 to $4.00 for soft, $6.00 to $8.00 for hard.
12	Steam	$7.00 for the sizes and $5.00 for pea.
13	Hot Water	Hard coal $10, soft coal $7.00.
14	Steam	$3.50.
15	Hot Water	$2.50 to $2.75 per ton of 2000 pounds.
16	Hot Water	$3.00 to $4.50.
17	Steam	$2.85 to $3.25.
18	Steam	Nine to 11 cents per bushel, averaging say $2.50 per ton of 2000 pounds.
19	Steam	Lump coal $3.00 per ton of 2000 pounds.
20	Steam	Lump coal $2.75 per ton.
21	Steam	The cost of coal to the various steam-heating consumers would approximate a price of, for run-of-mine lignite, $1.75; slack lignite $1.25 per ton delivered.
22	Steam	$7.00 per ton delivered.
23	Hot Water	Hard coal $10.
24	Steam	$2.90 per ton.
25	Steam	$3.50 to $4.50.
26	Steam	14 cents per bushel of 76 pounds.
27	Steam	Not given.
28	Hot Water	Soft coal $6.00, hard coal $10.50.
29	Steam	$2.50
30	Steam	Domestic coal costs about $3.50 per ton.
31	Steam	Native $3.50, anthracite $7.50 per ton of 2000 pounds.
32	Steam	From $5.00 to $6.50 per ton for anthracite.
33	Steam	$4.25, soft coal.
34	Steam	$2.00 to $2.25. This price also refers to 1902.
35	Steam	$1.85 to $2.00, slack.
36	Hot Water	$8.50 per 2000 pounds anthracite.
37	Steam	Varies from $3.00 to $5.75.
38	Steam	Not given.
39	Steam	$2.00.
40	Steam	$7.50 for hard coal, $4.50 for soft coal.
41	Hot Water	$9.50 per 2000 pounds anthracite.
42	Hot Water	Soft $6.00, hard $10.
43	Steam	$4.25 to $6.00.
44	Hot Water	$3.00 to $8.00.
45	Hot Water	At present $4.50, hard coal $7.50.
46	Steam	$4.00 to $6.50.
47	Steam	$6.25 per ton delivered.
48	Steam	Anthracite $8.50 to $9.50, bituminous $3.00 to $5.00.
49	Steam	Average price $6.50.
50	Steam	About 11 cents per bushel.
51	Steam	$4.50 to $7.00.

COMPANY	SYSTEM	
52	Steam	From $3.00 to $4.50, depending upon quality, amount used, and length of haul.

QUESTION 24.

As a result of your experience, do you consider, from all points of view, that your investment in the heating business was a good thing?

1	Hot Water	We do.
2	Hot Water	Very satisfactory thus far.
3	Steam	Yes.
4	Hot Water	No.
5	Steam	Yes.
6,	Steam	Yes.
7	Steam	Yes; we could even furnish live steam and make some profit; but when we take into account our exhaust steam from our electric plant, which, for the heating season, is from 25 per cent to 30 per cent of our heating requirements, in addition to this we make a very fair earning on the steam and electric plant combined; thus far we have practically run them together; but our net receipts from the electric plant have appreciated quite a bit since the installing of our steam plant. Of course the profit on our steam-heating proposition increases in proportion to the increased volume of exhaust steam, and our prospects seem better as we increase the development of our electric plant. We should say that any electric company having a large amount of exhaust steam ought to install a steam-heating plant in connection, as there is certainly good money to be made from selling exhaust steam.
8	Steam	We prefer lighting and power business. We are running all of our engines condensing, so we use live steam on heating system. We do not think there is much money in it.
9	Hot Water	Yes.
10	Hot Water	No.
11	Hot Water	Yes.
12	Steam	No.
13	Hot Water	Our plant has been fairly profitable and would be very much more so if we had sufficient day load. Heating plants can certainly be made to pay. As a rule they are a great deal of trouble and require constant attention. This is especially true of a hot-water system, although I consider the hot-water heating system more efficient than the exhaust-steam heating system.
14	Steam	Yes.

COMPANY	SYSTEM	
15	Hot Water	Unless plant goes to pieces like the "one-hoss shay"—without warning—yes.
16	Hot Water	Yes.
17	Steam	We consider heating plant good thing. Gives perfect satisfaction to customers and pays 12 per cent on investment.
18	Steam	All things considered, yes.
19	Steam	We consider the heating business a desirable adjunct to our business.
20	Steam	We could make more money by expending same amount in securing new electric business.
21	Steam	We have no hesitancy in stating that after having had an experience of three years in steam-heating business, the first year using live steam and the past two years using exhaust steam, that from the latter standpoint our investment in the heating business was a profitable one.
22	Steam	Haven't had time to think otherwise.
23	Hot Water	Yes.
24	Steam	Yes.
25	Steam	Yes; if you get a high enough price to start on. Coal has doubled on us since we started and we have advanced the price only once, from 25 cents to 37½ cents. Should have had 50 cents from the start, 10 per cent off if paid in 10 days. This is per 1000 pounds condensation meter basis.
26	Steam	We do.
27	Steam	From financial results and the general good will of the public, the heating system has been of great benefit to our company and has placed us in a position to defy competition.
28	Hot Water	Yes.
29	Steam	I guess so.
30	Steam	We consider its chief advantage is in enabling the company to discourage the installation of isolated plants.
31	Steam	Yes.
32	Steam	Yes; the system is eminently satisfactory to our customers as well as to ourselves. The company pays eight per cent dividend. We estimate that our net earnings on steam heating are about 75 per cent of our income for steam service. The cost of operating is limited almost to interest on investment, the cost of extra back pressure on our engines and wages of one man. We are so well satisfied with our experience in steam heating that it is quite possible that we may conclude to extend our sys-

COMPANY	SYSTEM	
		tem very considerably, using live steam for such extension, as we now have about all we can take care of with our exhaust.
33	Steam	Yes.
34	Steam	The answer to this question can be inferred from the foregoing.
35	Steam	Yes.
36	Hot Water	Not a good thing. We regret the investment. We operate largely with water-power and do not have much exhaust steam for heating.
37	Steam	We do.
38	Steam	We consider the system perfectly satisfactory, and shall probably extend the mains the coming summer.
39	Steam	We certainly do.
40	Steam	Up to our present investment, yes; but for any further investment, no.
41	Hot Water	No.
42	Hot Water	Yes.
43	Steam	We believe it is a good paying investment provided it is not necessary to use live steam with the exhaust to keep up the pressure. When live steam is used in connection with exhaust it becomes expensive to operate, on account of the pipe being too large and becoming a medium of condensation for live steam before reaching the building to be heated. I would advise against the extension of exhaust-steam system further than exhaust steam will supply. We made the mistake of doing this.
44	Hot Water	Yes.
45	Hot Water	Yes. Thus far we are able to utilize what exhaust steam we have, and as a certain amount of exhaust steam will take care of so much radiation, over and above that, it is necessary to use live steam or perhaps fire an extra boiler. Our experience prompts us to say that when it becomes necessary to resort to such a plan the conditions must be most favorable, *i. e.*, coal at a very fair or low price and practically no leaks in the mains and service.
46	Steam	Yes.
47	Steam	Yes.
48	Steam	Not given.
49	Steam	We are inclined to answer "No" to this question, but it is only fair to say that the business here was not started in the proper way. It is possible that the adoption of economizing coils and meters might materially change the results.

COMPANY	SYSTEM	
50	Steam	No.
51	Steam	Yes.
52	Steam	We are not prepared to say.

SUMMARY ON THE DATA RECEIVED

Taking the tabulated statement, as a whole, it seems clear that the companies that are in the heating business are generally successful. Out of 35 steam systems, 31 state and show by figures returned that they are well pleased with their investments. Out of 15 hot-water systems, 11 are satisfied, and four are not.

The best financial showing is made by those companies that charge by meters and cubic feet of air space, and insist on the use of economizing coils; that inspect and supervise the installation of buildings, and refuse to connect or give service to poorly designed heating systems; that keep separate accounts of heating and electric revenues and expenses; that have recognized the value a heating system is to the electric light and power supply.

It is, at least, a coincidence that the companies making the poorest financial showing are those that, from a lack of knowledge of what they are actually doing, are unable to make definite or explicit replies to some of the questions asked.

Replies to question No. 16, to the effect that no difficulty is apparent in securing or retaining heating patrons, would indicate that in most cases companies are not receiving as much for heating service as it would cost the customer to do the same work, and prices might properly be advanced. The comparative costs of steam and domestic fuel do not seem to enter into consideration when central-heating service has once been experienced.

Very few companies would change methods of construction, and only a few of the oldest plants report difficulties with the main lines. Seven companies refer to changes on service line that would be of benefit.

The important charge of depreciation has not had the consideration we feel should be given; only 21 companies of the 52 reporting see fit to provide for this.

On repairs, most companies report low costs; one com-

pany (No. 34), in business 16 years, reports only "about 2.5 per cent on mains and services."

The question of returning condensation to power-house seems to be one of local conditions. Very few express favorably on constructing plant to obtain this result, while a few are much in favor of it, probably due to local situation.

Replies to question No. 24, on satisfaction obtained from investment, seem to indicate that "District Heating" *is now a success* and can be made more so if central-station managers will co-operate with the committee for the general good.

As a matter of interest, the committee would state that the geographical distribution of replies received to the circular letter of inquiry sent out is as follows: Alabama 1, Connecticut 1, Colorado 1, Georgia 1, Indiana 5, Illinois 8, Iowa 7, Kentucky 1, Kansas 1, Maryland 1, Missouri 1, Massachusetts 1, Michigan 3, Minnesota 2, New York 2, Ohio 4, Pennsylvania 6, North Dakota 1, Rhode Island 1, and Wisconsin 2.

The committee especially desires to express its sense of appreciation for the splendid response to its questions on the part of operating companies. Such hearty co-operation can not fail to be of widespread and lasting value to every one, however remotely interested in this enterprise.

Yours very truly,

Committee, $\left\{\begin{array}{l}\text{E. F. McCabe, Chairman,}\\ \text{D. F. McGee,}\\ \text{C. R. Maunsell.}\end{array}\right.$

LIST OF QUESTIONS

DISCUSSION

The President: This report is now open for discussion.

Mr. C. H. Parker (Boston): Mr. President, the report of the committee on district heating is excellent, and great credit is due the committee. There are, however, a number of points not touched upon in the report which seriously change the simple building-heating proposition in this city. I have been intimately connected with two steam-heating systems in Boston in the past, neither of which could be reduced to the simple proposition of heating buildings in the cold months, as the customers demanded high-pressure steam all the year round for cooking and power purposes. One of the systems comprised five hotels, one lunch-room and bar, one theatre, one turkish-bath parlor, and eleven other buildings. The total radiating service of this system was a little over 30,000 square feet. In order to get this on our system we had to give high-pressure steam all the year round to the following apparatus: Five large hot-water heaters, one hot-water urn for afternoon tea, and so forth; eleven coffee urns; ten dish-warmers; five steam tables or serving tables; twenty-three stock kettles and vegetable boilers; one live steam jet for hot water; one oyster-stew pan; one egg-boiler; one dish-washer and engine; two elevator pumps; one ammonia compressor on refrigerating system, and seven small pumps used for pumping bilge-water from basements below the level of the main street sewer. Altogether, there were sixty-nine pieces of apparatus taking high-pressure steam all the year round.

Some of them, of course, could be put on a condensation meter, but some of them blew the steam right into the material to be cooked and these could not be metered. There was no way of estimating with any accuracy what their all-year consumption was, as a test made one day might not come within 100 per cent of what it was the month before or what it might be the next month. Of course, the steam ends of the engines and pumps could be displaced by electric motors, and it would pay to do this on a system that was expected to continue indefinitely. A careful test of four months' duration in this high-pressure system showed a yearly consumption of about 3500 tons of coal, while the heating of the buildings used 1700 tons of coal during the season. The four months' test referred

to showed that the heating system was returning a good profit but that the power system—as I have called it—was not. This whole business was given up when the station was shut down and turned into a substation.

The other heating system was not so badly handicapped with high-pressure steam customers, but still there were some, notably a large lunch-room doing practically all its cooking with live steam, a gold-leaf stamping concern, and a few elevator pumps and engines. There were twenty-two buildings heated by the exhaust from the engine, which was superheated about 125 degrees in the boiler flue. One and a half to three pounds was sufficient to do the heating in any weather. In the coldest weather, however, some live steam was needed, but not a great deal.

In this plant, also, the heating was very profitable, while the high-pressure steam system was unprofitable. There was very little on this system, however, that could have been measured by a condensation meter. Considerations entirely outside the heating question led to a discontinuance of this plant.

My experience shows me that a pure heating business can be made quite profitable in a city, even where live steam is used for heating, and that all the quantities are well enough known for the cost to be closely approximated; but when high-pressure steam is furnished for cooking and power the greatest care must be taken to determine the steam used, for the quantities will surprise the uninitiated. The only fair way is to measure all condensation by a meter. Do not attempt to supply steam to another man's engine or pump unless you assume at the same time all repairs needed to keep it in condition, for the owner of an engine paying flat rate for steam for it will not spend one cent for repairs unless he is forced to do so.

I should like to ask Mr. McCabe whether or not the conditions mentioned above obtain with other companies.

Mr. E. J. Richards (Newburgh, N. Y.): I ask if any of the members can give any information as to the deterioration of their mains in the underground construction?

Mr. McCabe: In answer to Mr. Parker's question—the committee made no investigation at all of high-pressure live steam. It has come to my attention during the past year that a great number of high-pressure steam plants were total

failures; therefore your committee did not feel like telling how to handle those plants, but preferred to take something young and vigorous, so confined its investigations to exhaust steam in connection with the electric-lighting and power supply.

As to the deterioration of the underground mains, I will say that out of fifty-two of the companies reporting only five or six made any charges for deterioration in underground mains. One company reported an expense of only 2.5 per cent for the maintenance of underground mains for fifteen years; another company, in business eight years, had no expense whatever for keeping up the underground mains.

Mr. Paul Doty (St. Paul, Minn.): May I inquire if the committee has considered to which account the net earnings from the operation of the steam plant should be credited? They submit a form for a comparative statement of revenue and expenses. They have on the form (line 15) "Net Earnings." What I should like to know is—is steam heating treated as a residual account and credited in the analysis of their operating expenses to the cost of coal for the steam generated, or do they treat the earnings from the steam-heating plant as an item of income and credit it to the gross earnings account? It is the practice of some gas companies to credit the revenue received from residuals to the cost of coal carbonized, and there are a variety of opinions as to whether or not this is the proper method of procedure. I should like an expression of opinion from the members of the committee in regard to the disposition of the revenues derived from steam heating as applied to the analysis of the electric operating expenses.

Mr. McCabe: It is the recommendation of the committee that the accounts be kept separate from the electric-lighting and supply accounts. We suggest that you charge to the heating account that amount of coal per kilowatt output used during the heating months above that used during the non-heating months, and for labor and expenses about the plant we recommend that you base your charges on the amount of coal fired in your boilers and charged to the heating system; in other words, if the cost of labor and other expenses about the boiler-room for a certain month were $100 and the amount of coal chargeable to the heating system was 25 per cent of the total used, we should charge 25 per cent of the cost of such labor and expense—or $25—to the heating system.

Mr. Doty: You do not recommend that the revenue be treated as the residual account?

Mr. McCabe: No; we recommend that they be kept entirely separate.

Mr. Richards: We recommend that it be kept as a separate account when possible. In our case we treat our exhaust steam as a residual and credit our coal account with the income from the sale of steam. We realize that this method is open to criticism, but with our present operating conditions we are not able to define what portion of our boiler-room expense is chargeable to steam heating and what portion to our electric-lighting service. We hope next season to be able to separate these items.

Mr. Doty: Your practice is not in sympathy with the recommendation of the committee.

Mr. Richards: It has not been so in the past, but we think the committee's suggestion a proper one generally. In our plant the only item of boiler-room expense affected by the heating business is that of coal.

Mr. McCabe: Very often, when you go to a man to sell him power, he tells you he has to heat the building. I have had that experience. He has two boilers to heat the building and it is his idea that he ought to be able to furnish power for electric motors from these boilers. It oftentimes happens that in our manufacturing establishments, in addition to supplying them steam from our underground mains we can also get a contract for supplying light and power, which we could not obtain if we did not have the steam plant.

Mr. Kimball: I do not think that the committee's report takes into consideration the distribution expenses, which include the proportion of expense of management, complaint work, and general expenses. There is no question but that these factors are an important part of the work.

In reply to the question of the gentleman as to depreciation on hot-water mains, it has been the experience in the several plants with which I am connected that there has been a great deal of money lost through leakage caused by expansion and contraction of these mains. This can be called repairs or depreciation. All plants that put in U bends for exhaustion joints have replaced them. Wooden boxing as insulation has a life of about ten years under ordinary conditions.

INCOME AND EXPENSE STATEMENT.

HEATING DEPARTMENT.

Month of __________________ *190*__

	INCOME.	AMOUNTS. This Year.	AMOUNTS. Last Year.	Increase or Decrease	Receipts per C. Sq. Ft. Radiation This Year.	Receipts per C. Sq. Ft. Radiation Last Year.
191	Radiation, Dwellings, sq. ft. @					
192	Radiation, Stores, etc. sq. ft. @					
193	Range Boilers, @					
196	Total Radiation Supplied, sq. ft. @					
197	Used at Station, sq. ft.					
198	Used at Office, sq. ft.					
199	D. H. sq. ft.					
200	Total Radiation Accounted for sq. ft.					
201						
202						
203	Forfeited Discount					
204	Total Receipts					
205	Less Allowances and Rebates					
209	Gross Income from Heating					
	EXPENSES.				Expenses per 100 Sq. Ft. Radiation. This Year.	Last Year.
	PRODUCTION:					
161	Steam					
165	Miscellaneous Supplies and Expense					
166	Total Above Items					
167	Heating Plant Labor					
168						
169	Total Cost of Production					
170	Heating Plant Repairs					
171						
172	Total Cost Delivered to Mains					
	DISTRIBUTION.					
173	Complaints and Gratuitous Work					
174						
175	Office Expense					
176	Executive Salaries and Expense					
177	Taxes Accrued					
178	Legal Expense					
179	Incidentals					
180						
181	Bad Debts					
182						
183						
184	Main Repairs					
185	Service Repairs					
186						
189	Total Distribution Cost					
172	Total Cost Delivered to Mains					
190	Total Cost of Heat Delivered					
210	Earnings Heating Department					
209	Income as above					

I submit a form that seems to cover all items that I think would be of general interest.

Mr. Arthur Williams: It is unquestionably true that in negotiating large contracts the supplying companies suffer great disadvantage through their inability to supply steam for heating purposes. The suggestion is frequently advanced that, having to maintain steam service, the additional cost of supplying electric light and power from that source is very slight; or that through the operation of a plant the exhaust steam will be sufficient for heating, and heat may therefore be obtained for nothing. In this argument sight is lost of the fact that the building must be heated before occupancy. At that time there can be no exhaust steam unless the machinery is operated unnecessarily and therefore extravagantly; consequently only live steam can be used. Steam supply, through the complication of a steam engine or pump, is obtained with an average expenditure of fuel of not less than 10 pounds per indicated horse-power; sometimes as high as 20 pounds. Steam heating directly can be obtained by an expenditure of five pounds of coal per boiler-horse-power. A good rule to follow in connection with this matter is to estimate one boiler-horse-power for every 8000 to 15,000 cubic feet of contents. The smaller number relates to hotels, apartments and office buildings, and the larger to department stores and buildings of that nature. Such factors as window area and exposure will, of course, enter into final calculations, but the figures given are sufficiently general and broad to enable anyone to obtain an approximately accurate result. The coal consumption should be based upon an average demand of three-fifths of the maximum and an average consumption, as before stated, of five pounds of coal per boiler-horse-power. The possession of these figures will be found an advantage in negotiating contracts in which steam-heating service enters as a factor in the final determination.

In a number of instances we have offered to supply steam from the boilers on the premises, using our own men and fuel. In no instance has the offer been accepted, but through the medium of a low maximum cost placed upon the heating service it has had the effect of bringing us the desired contract. It will be found, finally, that heating service can be supplied at a cost to the company of from .2 to .35 cent per cubic foot of contents, depending upon the size and character of the building.

THE PRESIDENT: If there is no further discussion we will proceed to the next report, "Office Methods and Accounting," by Mr. Frank W. Frueauff, of Denver.

REPORT ON OFFICE METHODS AND ACCOUNTING

To cover this subject properly one must consider office methods and accounting to embrace all the records and reports used in each department of the business, as from these records and reports all the final results are obtained.

The writer believes that to an incomplete system of records, or to a loose handling of a good system, much of the trouble of management, many of the complaints of consumers and the public, and the failure to secure satisfactory earnings may be traced. The company loses much in not securing the best efforts of its employees through failure to know just what they are accomplishing, and can make many savings in operation and great increase in its profitable business by knowing through complete accounting records the cost of results secured in each department and from each class of service. The failure to go into the accounting end of the business to a minute degree has resulted in many companies not knowing where they were drifting in the matter of taking on of new business and has kept them in the dark where an accurate statement of operating results would show an opportunity to make a big saving by some slight expenditure in the proper place.

I shall make no attempt to go over the systems in use in each department, but will attempt to show briefly some of the newer methods employed and the benefits from them.

The lighting companies throughout the country are all making an effort to increase their sales of current either to present users or new consumers, or by taking on business that was formerly done by isolated plants or other forms of power. These conditions have necessitated a much closer study of costs and receipts and have resulted in a much finer separation of the items entering into the cost of production for any particular class of current or for consumers using service in an unusual way. The usual method of grouping all expenses under the three arbitrary heads of manufacturing, distribution and general expenses and making separation under them for different sub-divisions

desired, has only given average costs and must therefore be misleading for purposes of figuring for new business to be secured or for analyzing present results in order to know the profitable from the unprofitable business.

The plan of apportioning the costs of operation to the class of current made and of separating fixed and variable costs, has therefore come to be a necessary part of a company's report of operations. This plan is now in operation among a number of companies with marked success. (For analysis of steam generation see Appendix.)

The expenses occasioned in manufacturing and distribution for any one class of current are kept distinct from those incurred in another, so that the actual cost of manufacturing and delivering arc, power or alternating current is known separately. These costs for any one class are also separated to show the costs that are fixed as distinct from those that are variable. For example, station foreman, meter department, shop expenses, etc., are practically a fixed expense, that is, they are an expense resulting from the size and running of an electric business and do not noticeably vary as the business may increase or decrease. Some expenses depend upon the amount of current made and sold; that is they vary with the output. For example, boiler fuel, firemen, lamp renewals, carbons, and so on. A third class of expenses is made up of those that vary with the number of consumers supplied or number of meters in use. Under this head may be included meter repairs, arc-lamp repairs, service repairs, meter-reading expense, collection and office salaries.

With the cost of current for any class of current separated into these three divisions, it is possible to know just what results are being obtained. You may then know whether or not your output expenses are increasing at a greater rate than the output and if the expenses proportioned to consumer are increasing faster than the number of consumers. In figuring rates to be made to secure new business this plan of separating costs is particularly valuable. For example, in figuring to take on a long-hour burning consumer you know from the figures of costs that the fixed costs will not be materially increased, nor will the consumer expenses, and that only the output cost will be increased. You may therefore assume that this business can be secured at a very low figure and still show a much larger mar-

gin of profit than business that will add to your expenses of capacity or consumers while only showing a small amount of current used.

COMPLAINTS

The electric companies are now realizing as never before that a satisfied consumer is one of their best assets. To make or hold these satisfied consumers requires constant and careful watching. A department of the business is established where these complaints are received and adjusted. They must be systematically followed up or great dissatisfaction will result. One plan in use is to record all complaints as received, showing the date, name, address, time complaint was received and nature of complaint. From this record typewritten orders in duplicate are made on a 3 x 5 slip, the original being sent to the inspection department immediately and the duplicate being held to insure the return of the original. The order is given to an inspector, who attends to complaint as carefully as possible. He notes on the order the result of his investigation and signs it, when it is returned to the order or complaint department. The date of execution and name of man is entered on the record and the duplicate taken from the pack of outstanding orders. A reply postal card is then made out from the (see Figure 1) order, stating that complaint had been made of certain trouble and asking if our inspector had attended to it satisfactorily, these cards being sent in answer to all complaints. The reply cards do not all come back, but we are sure that if the investigation or work has not been satisfactory consumer will be sure to reply. If an unfavorable reply is received, an order is sent to inspection department calling attention to unfavorable report, and when work is again completed another reply card is sent. The original order is then sent to the filing room, where all orders of every class are filed by dates under the street number, this file being used for reference from time to time and giving a complete history of all work done by the company at any house connected to our system.

A daily report is made from the order record, showing the number of complaints received, separated by classes, and showing the number of each class for same day of previous year and the accumulative number received during the past month. This report is sent to the general manager each day and enables him

to keep in touch with the troubles coming up. At the close of each month a statement is prepared showing the number of complaints handled by each inspector and the number from which "unsatisfactory" reports were received on the reply cards,

REPLY POSTAL CARD

United States of America

THIS SIDE IS FOR ADDRESS ONLY

The Denver Gas and Electric Co.

405-415 Seventeenth Street,

Denver, Colorado

Form 332 2M -2-04

Denver, Colo., ...

On. .... 1904, you reported ....

....

Kindly fill out the return postal card, stating whether the matter has been attended to, to your satisfaction.

Your prompt reply will be appreciated.

Yours very truly,

THE DENVER GAS AND ELECTRIC CO.

TELEPHONE 4000 405-415 SEVENTEENTH ST.

FIG. 1—RETURN POSTAL CARD

also showing the per cent of satisfactory work done. This report, after being inspected and signed by the general manager, is posted in the inspection department where all men can see it. This plan of compiling the efficiency of the men has a

splendid effect in stimulating them to careful and thorough work on all orders, and means a saving of time and money to the company and better feeling on the part of the public.

BUREAU OF INFORMATION

A new departure in the office is the establishment of a "bureau of information." This bureau is located in the most conspicuous point in the office and is in charge of a clerk thoroughly posted on all general matters of the company. His duties are to direct any and all inquirers to their desired point, such as application window, teller's window, manager's office, appliance department, etc. He has charge of the list of desirable vacant houses in the city, and upon request directs the inquirer to the real estate agent who has the property in charge. This list of houses includes only those along the company's lines or mains and only those that are equipped to use the company's service. By this plan we are able to get newcomers to the city, or those intending to move, to occupy houses where we can supply them without further investment. The list is revised each day by reports made from the soliciting and application departments of houses connected and disconnected. In connection with the bureau of information, bulletin boards have been placed at each plant, shop and department of the company. Upon these boards any announcements of changes of regulations, special inducements, information of particular importance to employees and copies of all new advertising matter being sent out are posted, in order that the employees in every branch of the business may be kept in touch with what is going on, and may be in position to talk intelligently if questioned when attending to their duties, or after hours.

METER READING

One of the most important requirements for satisfactory relations with consumers is the necessity for accurate meter reading and billing. The coupon system of meter-reading cards, originated by Mr. S. J. Glass (see Figure 2), seems to be the best and safest method in use. Under his plan a slip with 12 coupons attached is made for each meter; each coupon bears an identifying number, corresponding with the account on the consumer's ledger. After the meter has been read and bill made

the coupon used is detached and filed for reference. The meter reader then has only the meter number and house number to direct him when he next takes the reading. By this plan no readings can be averaged or readings put down without actually seeing the meter, and as the man has no previous reading to assist him, he must use unusual care to get the correct figures.

By keeping the same men reading each month and through-

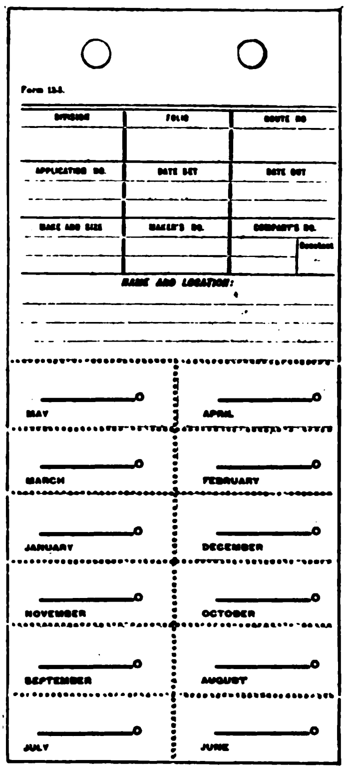


FIG. 2—METER-READING CARD

out the month and not picking up extra men each month to take statements, a considerable saving can be made, as men familiar with the routes can make much faster time and will not have to go back to get meters skipped or read wrong on the first trip. The plan of posting a list of all mistakes made

by the meter readers will also increase the efficiency of this department. At the close of each month a list is posted in the department showing the number of meters read by each man and the number of errors discovered. A bonus is paid to each man who makes no mistakes during the month. One month's records show 13 men read 32,000 meters with a total of but eight errors made by all these men.

OFFICE MISTAKES

The plan of recording and then posting a list of all errors made by the consumers' bookkeepers is followed. In this list appear any errors or omissions made by them, including errors in extensions, or calculations, failure to send bill to proper address, omission of balance owed for previous period, and so forth. This posted list has the same stimulating effect as the lists of errors made by the meter readers and trouble-men.

In the general office a Dey registering time clock is used. All office employees are required to register as they come into and leave the office. From this record the office time is kept. We find it of particular value in impressing promptness upon all employees; and as clerks are on duty from seven a. m. to midnight, it is possible to know the time they arrive and leave without requiring the chief clerk or a time-keeper to note their movements. A list is posted each morning of any who have registered late in arriving or who have overstayed the hour off for lunch. At the close of each month a list is made of those who have been prompt and punctual throughout the month.

CARD RECORDS

The use of card index records in offices is constantly growing and is satisfactory for most purposes. We are now using a house record (see Figure 3) index in our application and order department. A card was made for each house connected, and as orders were taken to connect, disconnect, or change meter, arc lamp, etc., a posting to this effect was made on the house card; after the order had been executed the date of execution was entered on the card, so that we constantly have a record of our standing at each house. This has done away with all duplicate or wrong orders. Under the old plan of listing orders in a book or books we frequently sent men to

re-read meters for a new tenant when we had just ordered the meter returned on instructions from the old occupant; but with the house card to refer to before sending order to shop for execution, a wrong order is detected and new one substituted to cover the latest development, or the order previously sent out is ordered recalled.

Visible-writing typewriters with card-holder attachments are used on all orders of every description. We find by their use fewer errors in copying or reading addresses and that names of consumers, being more legible than when written by hand, are

STREET								No.
Order Number	NAME	Nature of Order	Date Issued	Date Executed	Ill. Gas Meter No.	Fuel Gas Meter No.	Electric Meter No.	Index

FIG. 3—HOUSE-RECORD INDEX

correctly carried through the records and to the addressing machine.

The filing cabinet referred to before is also a feature in the card system. A guide card is placed for each street and number, and back of it are filed all completed orders for setting or removing of meters, complaints, connection of appliances, etc. If it is desired to refer to any original order, it is readily located by this plan.

For the record of stock of materials carried, a loose-leaf system is in use. One sheet is arranged for each article, showing amount on hand and received in one column, the amounts

sent out in another, and a column to show the running balance of materials on hand. This record is kept to show both the quantity and value of each article in stock, and is kept up each day from the storekeeper's reports of materials received and sent out.

ACCUMULATIVE REPORTS

After the monthly report is complete, the records therein shown are transferred to loose-leaf sheets containing columns for every item on the report; these figures are carried on an accumulative basis and always show the results for the past twelve months, this being done by adding or deducting the difference between the last month and the corresponding month last year, from the previous yearly total. These accumulative figures show much more clearly any real increase or decrease, and are not misleading, as the results for any one month might be. From these accumulative sheets a year's report can be made without any trouble or delay.

OFFICE LABOR-SAVING DEVICES

In Mr. Anthony's paper, read before the convention last year, he described several of the labor-saving methods in general use. I will therefore refer only to some not mentioned by him.

RECEIPTING MACHINE

We use a Boettescher and Knecht machine in the teller's cage for receipting all bills. This machine is driven by an electric motor. The bill is placed in front of the machine by the teller, who then touches a spring; this releases the lock and sets the machine in motion, the bill is drawn under the roller, the coupon cut off and dated and dropped in a drawer below and the receipted bill forced out to the front of the window, where it may be picked up by the consumer.

ADDING MACHINE

We are now using an adding machine made by the Universal Adding Machine Company, of St. Louis, which has an electric driving attachment. Instead of pulling down a lever, as with the usual adding machine, a spring is touched which sets the machine in motion and performs the same office as the lever.

SELF-ADDING SHEETS

These are a simple arrangement used in tabulating results (see Figure 4), such as number of meters or consumers gained or lost, and so forth. The sheets are ruled for units and every tenth space is so marked. When all marks are down the number of vertical spaces times the number of horizontal spaces used shows the total desired.

SLIDE RULE

The slide rule frequently used in engineering work can be made to play an important part in modern office methods. Clerks can be easily instructed in its use and calculations requiring multiplication or division worked out in much less time than by the old methods.

THE THATCHER CALCULATOR

This machine made by the Keuffel and Esser Company, of New York, we have found the greatest labor saver yet tried. All costs and receipts are worked out on the reports on a basis of current made or sold. With several hundred separations, it will require a couple of days' time to do the division required. By the use of the calculator the results may be set down as fast as one can read the numbers on the machine. This machine is unique in construction and easily understood. Where a constant multiplier or divisor is used the results are shown more quickly than with any of the other calculating machines. This feature therefore makes it particularly valuable in use on monthly reports.

TUBE SYSTEM

A tube system, such as is used in department stores, has been of great benefit to us. We have connection at all windows in the accounting office direct with the bookkeeping and collection rooms. If a copy of a bill is desired or explanation required, the detail can be secured in much less time than by going to consult the books and leaving the consumer waiting. We are able to do all bookkeeping work on another floor of the building, which is away from all the disturbance of the public office. We find that by this plan our bookkeepers are able to handle more accounts and with fewer interruptions.

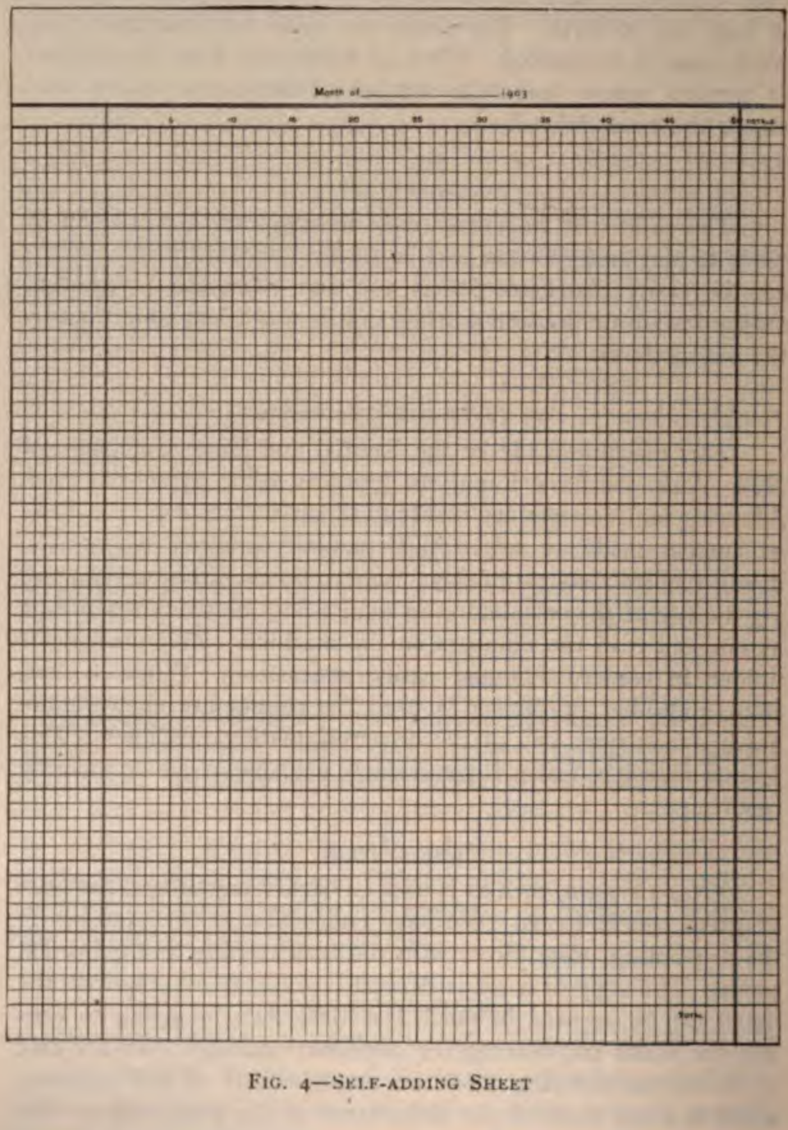


FIG. 4—SELF-ADDING SHEET

TABULATING MACHINE

We are installing a Hollreith electric tabulating machine. This machine is now in successful operation in a number of railway accounting offices, in some large factories, and was used by the United States Census Bureau in compiling its statistics. The equipment consists of two parts: The punch, into which properly printed cards are set, transfers the information by punching a hole in the proper space. When all information has been transferred to the punched cards they are set in the tabulating machine, which sorts them into several kinds and then compiles the information. It is our intention to use this machine to tabulate our records of all consumers, to show the possibilities of each class of business, and to use it in making up the payrolls. Use will also be made of it in our engineering department in keeping track of our current made, sold and lost, of the various types and efficiencies of transformers and meters.

Your reporter received his appointment at such a late date as to prevent his making inquiries among the different members as to their experience with any new office methods or labor-saving devices. I have therefore only mentioned some of the methods now employed in the Denver office. We have endeavored to keep in touch with all the newer plans suggested for accounting and for labor saving, and have adopted any that seemed to have advantages over those previously employed.

Respectfully submitted,

FRANK W. FRUEAUFF.

APPENDIX

STEAM GENERATION

ANALYSIS

This analysis is to enable us to determine what proportion of the generating expense should be charged to each class of current sent out from the station. The generating apparatus for the different kinds of service is usually not of the same efficiency. To compensate for this we apply the average efficiency of the apparatus to the output in kw-hours of each class of current.

This gives us at the throttle valve of the engine the equivalent of the output from each class of current. From this point the generating expenses proportional to output are common. Having this equivalent steam energy, we can divide the generating expense in the same proportion that this equivalent energy appears. This would give us expense proportional to output that should be charged to each class of service. The expenses proportional to capacity should be divided in proportion to the capacity of each class of apparatus in the station.

DISCUSSION

THE PRESIDENT: The paper is open for discussion.

MR. DOTY: I desire to say for the benefit of the association that Mr. Frueauff has described a very complete and modern method of keeping the records of the office work and office accounting. His system is practically in operation at Denver, and, as most of you gentlemen know, some good things come out of Denver. The report represents a great deal of careful work on the part of Mr. Frueauff, and I am sure the association is indebted to him for his care and his labor in the presentation of this report.

MR. A. S. KNIGHT (Boston): I am very sorry Mr. Frueauff is not here, because I am afraid that in his absence the discussion will not be especially profitable. I was anxious to ask him in reference to his method of distributing his expenses. He recites what appears to be rather a novel system of proportioning his expense and one that seems to me rather difficult to apply to large companies, and if there is anyone here representing him I should be glad to know more of the details in regard to the methods. He appears to classify them differently from the usual custom—applying to each class of his earnings a certain portion of the expenses.

MR. DOTY: Mr. Irvin Butterworth, the president of the Denver company, is here; perhaps he can answer.

MR. BUTTERWORTH: I do not think I can go into that subject on the present occasion sufficiently to make it of interest, but the system can be explained in private conversation with any of the gentlemen at any time. The system at Denver follows that employed in all the gas and electric companies of which Mr. Emerson McMillin is the head. The various managers

appointed a committee to devise a uniform system of accounting, and that committee perfected the system that we are all following. We think the results obtained by it are very satisfactory.

Mr. Burnett: I inquire of Mr. Butterworth if the committee of which he speaks took into account this question that recently arose in a case in which I am interested: We have been dividing our expenses into general expenses, cost of manufacture, and cost of distribution. I should divide these costs as follows: Cost of generation, cost of distribution—namely, the cost of bringing the current to the meter—and then cost of application; that is, on the customer's side of the meter, which would include the cost of maintenance and trimming of arc lamps, incandescent renewals furnished free to the customer, and any special wiring done to secure the customer's business, installation of electric signs, and so forth. Is it desirable to separate the cost of application from the cost of distribution?

Mr. Doty: I will say, in reply to the question of the previous speaker, that the four general heads into which the electric operating expenses are divided are: Manufacture, distribution, collection, and general expense; and, in addition, distribution and collection expense are divided proportionately to the "consumer's charge" and the "meter charge." Further, an analysis is made in order to determine a proper proportion of "fixed" and "variable" operating expense; that is, expenses proportional to "output" and "plant." There is a separate account for "promoting new business," to which is charged all the expense incurred in securing the business.

The President: If there is no further discussion we will proceed to the paper on "A Proposed System of Standard Instruments for Operating Companies," by Mr. H. P. Davis, of Pittsburg.

Mr. Davis read the following paper:

A PROPOSED SYSTEM OF STANDARD INSTRUMENTS FOR OPERATING COMPANIES

Electrical engineering is an exact science. Its units of measurement are definite and precise, and permit accurate calculation of minute quantities. In the design and manufacture of electrical appliances, the mathematical formulæ used and the engineering methods adopted result in a degree of exactitude that is not equalled in any other branch of commercial science. With the increase in electrical knowledge and the widespread industrial adoption of this form of energy for the production of power and light, the requirements of apparatus have become more severe and the standards of efficiency have grown constantly higher, until the laboratory standards of a few years ago have been transferred to ordinary commercial service, and the present basis of operation is one which a decade ago would have been deemed academic and unpractical.

The causes for this state of affairs are not hard to find. The development of electrical devices has been eagerly pursued by a host of inventors and engineers, and there is keen rivalry in all parts of the electrical field. To generate electricity at the lowest cost; to transmit and utilize the greatest proportion of the energy produced and to measure most accurately the output and consumption, are the ends sought in modern electrical engineering, and the eager strife to achieve preeminence has done much to raise the standards of accuracy to their present point.

The managers of central stations have also done much to induce a higher standard of efficiency by their careful and constant balancing of coal against kilowatts, their active search for possible leakages, and their readiness to adopt new devices which promise to yield better results. Generator losses, transformer losses, line losses and meter losses have received unremitting attention, and the manufacturers of electrical appliances have found that the only articles that are received with favor are those that show a high standard of efficiency and accuracy in performance. Instances are known where station managers who have made a change in transformers have changed an annual deficit into a dividend, and where those

who have replaced old types of service meters with modern instruments have found that the production recorded at the station has closely approximated the sum total of the service meter readings. Thus engineers have been spurred to greater efforts, not only by a rivalry among themselves, but by the urgings of the users of electrical appliances whose demands create the market. There is no other line of appliances in which efficiency counts for so much and in which a reduction in price to compensate for an inferiority in design or performance offers so little attraction.

Increased efficiency in the generation and utilization of electricity necessitates increased accuracy in the instruments designed to measure production and consumption, and the service instrument that will not in actual practice operate within two per cent of accuracy is not considered worthy of consideration. The sensibility of the laboratory appliance is combined with the strength and stability of the field instrument, and the result is a system of measuring devices that with proper care will give exceedingly accurate results.

Such instruments require occasional tests and comparison with standard instruments of undoubted reliability, for their extreme sensibility and delicacy of adjustment make them as liable to injury from the wear and hardships of usage as other high-grade mechanical devices of similar nature. The testing or standard instruments to be of value must be superior to those with which they are compared, possessing great readability and accuracy, permanency of calibration, simplicity and convenience in manipulation, and freedom from disturbance by local influences.

That the instruments now used as standards are painfully inadequate for many kinds of work, and are lacking in many important particulars, is well known to those at all familiar with the subject. Those that have the desired accuracy and reliability are complicated and require an unusual degree of skill and painstaking in their use, while those that are most generally used and have the advantage of portability and ease in handling, have secured their superiority in one direction by sacrificing important features in another and thus do not fully and satisfactorily answer the purpose for which they were designed.

As an illustration of the lack of adaptability of this latter class of instruments, the calibration of integrating wattmeters

them upon a fair commercial basis for the use of operating companies; and thus to give the purchasers the benefit of their exceptional facilities for designing, manufacturing and maintaining their accuracy in use?

It is not necessary that these standards take the place of ordinary portable instruments for the general run of service work in which a very high degree of accuracy is not required, but they should be provided for the calibration of other instruments, especially those requiring long ranges, such as integrating wattmeters, and practically to furnish in commercial form copies of the legal reference standards.

The service rendered by manufacturers of such standard instruments could, it would seem, be advantageously extended to cover their care and re-calibration after they were put into the hands of purchasers. The technical training required for their design and manufacture; the extreme nicety observed in every detail, which makes extreme accuracy a fixed habit; the exceptional facilities for calibrating and the possession of primary standards of the highest possible degree of accuracy,—all combine to make the manufacturers of these instruments the best able to care for them thereafter. They would be most familiar with the peculiarities of each instrument, and their records of performance, taken from time to time as the instruments were presented for checking, would enable them to give each an individual attention it would not otherwise have.

By taking upon themselves the responsibility for the perpetual accuracy of the standard instruments and by thus furnishing the purchaser with an insurance against inaccuracy, limited only by the length of life of the device, it would seem that their value to the user would be considerably enhanced, and their field of usefulness enlarged. There would be a distinct advantage in having such a service made as nearly universal as possible, and in having the care and calibration of such instruments centralized, in order that a uniformly high grade of accuracy might be secured, such as can not be obtained with the present system, in which the owner is interested only in the continued accuracy of his standard instruments, which come from various sources and are calibrated in different establishments.

A part of the trouble with prevailing standards is caused by the lack of attention to their re-calibration. This is

partly due, doubtless, to the cost of having the standards checked, and partly to the length of time ordinarily required for the operation. To render the best service under the plan suggested, the manufacturers of the instruments should make no charge for re-calibration, and should see to it that prompt return is made to the owners. It might even be found advisable to ask owners to send in instruments to be checked, when a considerable period had elapsed without such attention. The owner would be at no expense except for carriage, and should have no hesitancy in sending his instruments to the makers for attention when desired. The testing departments of operating companies would thus be kept in contact with a single standardizing bureau or department whose certificates should rank in excellence with those of the best and most favorably known government bureau or the most famous standardizing laboratories.

To render such a system successful requires an instrument far superior to all present types, and to cover the field properly the assortment should be made up of voltmeters, ammeters and wattmeters. Their principle of operation should be such as to give equal indications on either alternating or direct current, and they should not be affected by forces other than those they are required to measure, thus eliminating any influence of external fields. They should admit of very accurate readings of scale deflections at any point, and the estimation of fractional parts of divisions should be avoided so far as possible, especially if the divisions are unequal.

Moreover, their indications should be "dead-beat." To render negligible the effects of friction, the controlling force should be large, and the friction of moving parts small. This necessitates a support for the moving part to enable it to withstand a considerable amount of rough usage without injury or increase of friction.

The carrying capacity of the various circuits of the instruments should be such that no errors due to heating will be introduced, and in addition to this, the temperature coefficient of the instrument as a whole should be small.

The construction of the movable parts should be such that violent changes in the quantity being measured can produce no injurious results, and the instruments should be so made as to allow shipment or transportation with positive

assurance that the calibration will be unaffected from the consequent jars and shocks.

This presents what seems to be an ideal condition which may be made real. The present conditions certainly demand an improvement, and the method outlined presents what is believed to be a feasible and adequate remedy for existing deficiencies. Would it not be worth the while to attempt to bring about a new order of things? Would not a general feeling of confidence in its testing standards and an improvement in adaptability be welcomed by the operating companies in general? Would it not be possible, by a concerted effort, to bring into use a new system of standardization on these lines which will prove of sufficient value to repay the thought and labor expended upon it and shall be in keeping with the conditions in other portions of the electrical field? The subject is surely one worthy of consideration.

DISCUSSION

MR. DUSMAN: I think a statement about this matter was made two years ago, at the Cincinnati convention, and I should now like to know what progress has been made and to what extent we may avail ourselves of the bureau?

MR. H. P. DAVIS: So far as I know, the Government bureau is equipping to take care of this work. Its equipment is not sufficient, I believe, at present to take care of all lines, but it is gradually getting into shape.

MR. DUSMAN: Within the last three months I had a difference in the readings of some ammeters. The readings involved were only up to about 6.5 amperes, but the standard, as reported by one manufacturing concern, was .2 ampere out as compared with the test reported by the manufacturer of another instrument. Both claimed that the instruments had been tested by their standards in their very expensive laboratories. We are still waiting for a final report from them on this difference.

THE PRESIDENT: The next paper on the programme is entitled "Single-Phase Power Motors for Electric-Lighting Stations," by Mr. W. A. Layman, of St. Louis.

The following paper was presented by Mr. Layman:

SINGLE-PHASE POWER MOTORS FOR ELECTRIC-LIGHTING STATIONS

The single-phase alternating-current power motor may properly be considered by the central-station man from two points of view:

(a) The adequate performance of the motor, service conditions being satisfactory.

(b) The relative simplicity, cost and efficiency of the distribution system, the motor being entirely satisfactory.

The first consideration is the manufacturer's problem, and unless solved by him there is no occasion for a discussion of the second.

The writer's discussion of this subject is based upon the following assumptions:

First—That the single-phase motor, except for variable-speed work, is to-day the substantial equivalent of the direct-current motor.

Second—That polyphase and single-phase types of motors are not competitive.

Third—That simplicity of generating equipment and system of distribution are of paramount importance in the profitable development of central-station service.

In such a discussion, central stations divide themselves naturally into two classes—the large and the small.

The writer's views as to the proper form of alternating-current equipment and distribution for these two types of plants, are as follows:

(a) *For Large Plants*

Polyphase generators, with switchboard arranged for operating.

First—Polyphase feeders for all large power and rotary-converter service.

Second—Single-phase feeders for all general lighting service and for all small power work, the switchboard facilities being such that any single-phase feeder may be switched to either phase of the generator 'busses. Where a system of substations is employed, feeders from main to substations

should be polyphase with provision in the substation for polyphase power distribution in large units, and single-phase distribution for all other kinds of service.

Third—Independent feeder regulators for all polyphase as well as single-phase feeders.

(b) *For Small Stations*

Either single-phase generators with single-phase feeders, each feeder being operated with independent pressure regulator; or polyphase generators, with single-phase feeders that may be thrown by the proper switchboard devices to either phase of the generator, and each feeder provided with independent pressure regulator.

This policy with respect to station and distribution equipment is advocated in the conviction that the single-phase power motor affords the alternating-current station, polyphase or single phase, the ideal means for distribution of small power; also on the assumption that no valid reason exists why small motor service should not be given from incandescent-lighting distribution mains. I take it that every central-station operator prefers single to polyphase distribution, and that no central station engineer will extend polyphase distribution beyond the limits of the actual necessities from an economical and engineering point of view. It therefore remains only to establish clearly in any given locality the extent to which single-phase distribution meets all actual service requirements. Coming in contact with central-station men all over the country, in an endeavor to widen the use of single-phase motors, has enabled the writer to state that a wide difference of opinion exists between central-station men as to the extent to which single-phase motors should be employed and central-station distribution systems correspondingly modified. This difference of opinion arises from doubt on the following points:

First—That the single-phase motor is a reliable device.

Second—That the cost of installation of the single-phase motor is actually much less than that of the polyphase.

Third—That satisfactory single-phase motor service can be given from polyphase generators.

Fourth—That single-phase motors can be satisfactorily operated from lighting circuits.

Reliability of Single-phase Motors

That the single-phase motor is a practicable and reliable

device is evidenced by the fact that approximately 1500 motors are in operation in the city of Chicago alone. There are also many hundreds in Boston, Philadelphia, St. Louis, and other large cities, while in the smaller towns thousands are in successful use. Several manufacturers now advertise single-phase motors, and the company that I represent has been building them with great success since 1897. There is no question, however, that considerable scepticism exists as to the complete success of this type of motor. This scepticism is largely the outcome of several early attempts to exploit synchronous single-phase motors that were complete failures. There is also some indifference to the virtue of the single-phase motor where the polyphase system has been installed, and operating engineers are not familiar with the degree of success attained elsewhere with the single-phase motor. There are many central-station engineers in this association, however, who will bear me out in the assertion that at least one type of single-phase motor on the market to-day is thoroughly reliable and is comparable in practically every respect to the best shunt-wound direct-current motors, and also the best polyphase motors.

Comparative Cost of Installation of Single and Polyphase Motors

I have said above that polyphase and single-phase motors are not competitive. From the manufacturer's point of view they may be to some extent, but from a central-station and engineering point of view they are strictly non-competitive. The cost for installing a polyphase motor is so much in excess of the cost for a single-phase motor, that no central station can afford to give polyphase motor service where single-phase will meet the requirements. This excess of cost consists in line wire, cross-arms, step-down transformers, secondary wiring, meters, etc. I am informed by a prominent central-station engineer that he has been able to effect a saving of $100 in the first cost of service equipment for every 5-hp to 10-hp single-phase motor installed. The saving for the larger sizes of motors is considerably greater. As indicating the saving in transformers alone, see Figure 1, in which there is a comparison of transformer costs for single, two and three-phase motors.

This comparison is based on the adaptation of standard sizes of transformers. It will be observed that the excess in

cost of transformers varies from about 25 per cent for two-phase motors, to an average of about 50 per cent for three-phase motors, operating on two transformers. There is a further substantial and constant central-station saving in the core and copper losses of transformers, arising from the losses of two or three small transformers for a polyphase motor greatly exceeding those of one transformer for the same capacity in single-phase motor. See Figure 2.

The investment saving alone is leading some of the largest central-station companies to require single-phase motors for

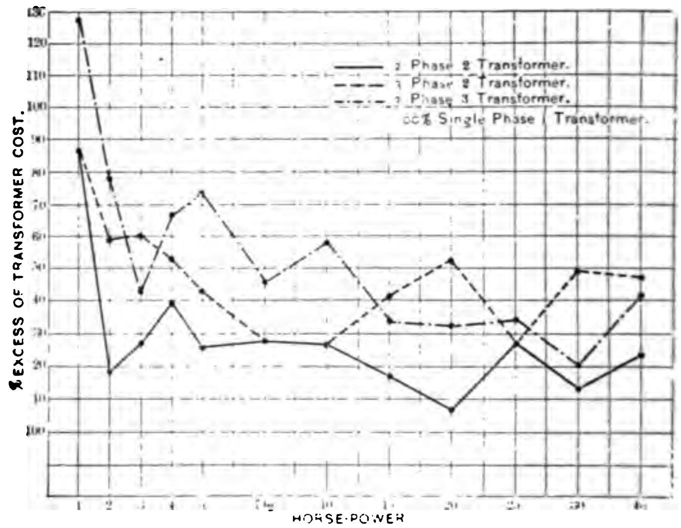


FIG. 1—CURVES SHOWING EXCESS OF FIRST COST OF TRANSFORMERS FOR MULTIPHASE AS COMPARED WITH SINGLE-PHASE

(These curves are based on price list of one of the large companies)

all installations within certain capacities. Taken with the saving in transformer losses, and the simplification of distribution system, this relatively low cost of installation is bringing about a radical change of ideas as to alternating-current distribution. One well-known engineer has stated that the saving in pole-line space arising from the use of single-phase feeders is alone a sufficient argument in favor of single-phase motors. Within the last year it has therefore come about that some of our best companies are no longer attempting a general poly-

phase distribution, but now run out polyphase feeders to large power units only.

Single-phase Motors on Polyphase Generators

The small central station has very little use for a polyphase generator. In not one small town in a hundred does there exist a single instance of power service that can not be adequately handled with a single-phase motor. A few years ago this was not the case, and some polyphase generators were installed in small towns. Recently many of these have modified their switchboard arrangement and are now operating generators as single-phase machines at approximately 80 per cent of the polyphase rating. In the larger cities, polyphase generators are justifiable, the multiplicity of single-phase

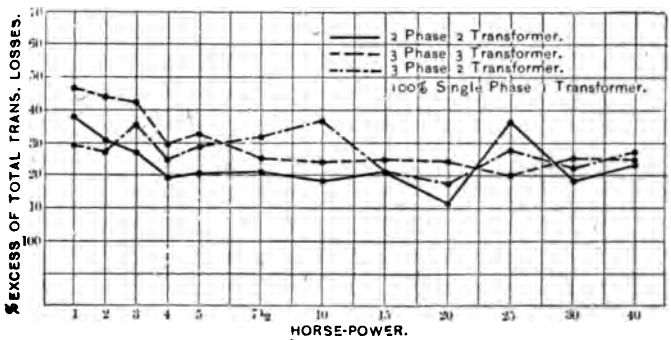


FIG. 2—CURVES SHOWING EXCESS OF TRANSFORMER LOSSES FOR MULTIPHASE MOTORS AS COMPARED WITH SINGLE-PHASE

circuits alone making them desirable. Single-phase service can be satisfactorily given from any polyphase machine. All the plants of the Public Service Corporation of New Jersey, approximately 15 in number, all those of the United Gas Improvement Company, also of the Boston Edison Company, the Philadelphia Electric Company, the Chicago Edison Company, the Cincinnati Gas and Electric Company, and a great many others, are giving thoroughly satisfactory single-phase motor service from their polyphase plants, and also from polyphase feeders. These stations are coming to regard the single-phase motor as offering difficulties not appreciably greater than an incandescent lighting load of the same size

subject to sudden application to their systems. I am informed that two of the largest syndicates—namely, the Public Service Corporation of New Jersey, and the United Gas Improvement Company—have determined upon a central station policy that calls for adherence, as closely as possible, to polyphase generators governed by automatic pressure regulators, with single-phase feeders controlled by individual pressure regulators. I am also informed that these companies have inaugurated a very energetic policy of expansion of single-phase motor service, using many of the same expedients to secure single-phase motor subscribers as are used by some of the leading gas companies in extending fuel-gas consumption. The balancing of the load on a polyphase system becomes in a considerable measure of minor importance when individual feeders are equipped with pressure regulators.

In the city of Chicago, the outlying substations are fed from the main generating plants by three-phase, four-wire trunk lines. From substations single-phase feeders are carried out, each of these feeders running from one side of the three-phase circuit and the neutral. Each single-phase supply circuit is equipped with an individual pressure regulator, and each feeder thus becomes absolutely independent of all other feeders, both as to load and pressure regulation. It is the practice in a great many polyphase plants to require the installation of single-phase motors for all service connections up to a certain point, and to give preference to single-phase installations above that point where the general distribution system will take the load without disturbance of lighting service. The Public Service and United Gas Improvement companies are installing single-phase motors up to and including 35 horse-power. The Cincinnati Gas and Electric company is using single-phase motors of 15 or less horse-power capacity, and considering larger installations individually on their merits. In Chicago, I am informed that motors of 5-hp or less are required to be single-phase, and larger installations are considered individually on their merits.

Sentiment is constantly changing, and the next year will see a rapid development of the policy of throwing down the bars to single-phase motor business, and confining the use of polyphase motors more and more to large service installations.

Single-phase Motor Service from Lighting Circuits

The difficulty of giving satisfactory motor service from lighting circuits, without the disturbance of lights, has been very largely overestimated. It has been the writer's experience that the factors necessary to satisfactory single-phase motor service from lighting circuits, in the order of their importance, are about as follows:

First—The control of feeder pressure by means of individual feeder regulators. The cost of these regulators is negligibly small when their value in the elimination of service difficulties is fully appreciated.

Second—Adequate feeder capacity for an equivalent total load of incandescent lighting.

Third—A sufficiently large and properly selected type of transformer. A transformer suitable for incandescent service will not necessarily be suitable for motor service, as some of the commercial makes of transformers that give good regulation on lighting load give very poor regulation on motor load. A properly selected lighting transformer will be entirely adequate for good motor service.

Fourth—Installation of the single-phase motor in such a manner as to hold down the current demand from the circuit in starting.

This last consideration comes back again to the operating characteristics of the motor. The motor with which I am most familiar, namely, that manufactured by the Wagner Electric Manufacturing Company, possesses two characteristics that contribute admirably to the minimizing of disturbance effects of frequent starting. These characteristics are:

(a) A very high power factor of starting current.

(b) A large excess of starting torque, which permits the use of a non-inductive starting rheostat, making possible the holding down of the starting current without loss of sufficient starting capacity.

The Wagner type of motor starts as a repulsion motor and at the instant of starting develops a torque of two and one-half times full-load torque for full-load current, or five times full-load torque for the maximum rush of current when rheostat is not in use. In sizes of 5-hp or less, it is the usual central-station custom not to use starting rheostat; for the larger sizes starting rheostats are now quite generally used. These boxes are of the standard direct-cur-

rent type, without automatic release, and when used, the starting power factor on the motor varies between 90 and 95, developing full-load torque from rest to full speed with a current that does not exceed one and one-fourth times full-load current. Where the motor load varies between wide limits and is of a pulsating character—which tends to set up current waves in the feeder—it is advisable to install a small flywheel, which serves to straighten out the current demand. Where large motors are located at the end of long feeders, it is also frequently desirable to require the starting of these motors on an idle pulley, in which case a negligible disturbing effect results. It is always well to use a transformer of

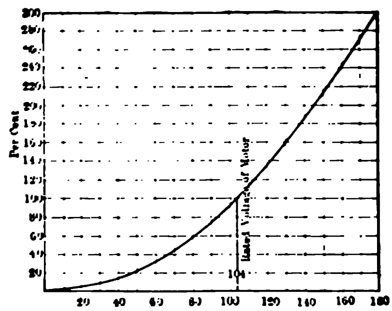


FIG. 3—VARIATION OF MOTOR OUTPUT WITH VARIATION OF VOLTAGE

ample capacity, since good single-phase motors are capable of carrying temporary overloads of from 30 to 50 per cent.

They will not develop such loads, however, without corresponding transformer capacity. As indicating how the capacity of an induction motor will drop off with a falling off of the line pressure, see Figure 3.

For normal full load, it is usually necessary and sufficient to install about one kilowatt of transformer capacity for one horse-power of motor capacity on 60-cycle circuits.

Single-phase Motors for High Frequencies

So far as I am aware, there is but one manufacturing company supplying single-phase motors for 125 and 133 cycles. The Wagner motor for these frequencies is not quite

so good a motor as for 60 cycles, but is in all respects adequate to good motor service. There is therefore no reason why small high-frequency plants still scattered over the country should, for the sake of securing motor load, abandon their existing transformer and generator equipments and adopt a lower frequency of current supply. There are a number of instances of central stations of 150-kw capacity giving 133-cycle motor service almost up to the maximum capacity of the plant.

The Desirability of Motor Load for Central Stations

The energetic development of motor load on large distributing systems is evidenced by the following load curves

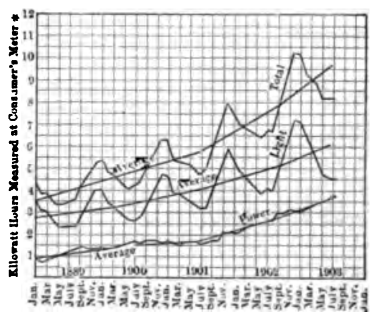


FIG. 4—KW-HOUR OUTPUT AT SERVICE METER, CHICAGO EDISON COMPANY AND COMMONWEALTH ELECTRIC COMPANY

(Scale only indicates relative figures, actual figures being confidential)

kindly furnished the writer by Mr. Louis A. Ferguson, of the Chicago Edison Company. It will be observed that on January 1, 1899, the average power load on the Chicago Edison circuits was 24 per cent of the total load. Observe the remarkable development of power business between that and July 1, 1903, when the average power load became 46.5 per cent of the total load. That the Chicago Edison contracting department was not neglecting the lighting business, is evidenced by the very handsome increase of 124 per cent in lighting load. But the energy with which the motor business has been pushed is indicated by the remarkable increase of 335 per cent in motor load. These curves leave no room for doubt as to why the Chicago Edison Company is making

such a splendid success of its business. As evidence of energetic development elsewhere, I am also able to furnish, through the courtesy of Mr. H. C. Hutchison, of the Cincinnati Gas and Electric Company, the following curve showing the expansion of their motor business during the last six months of 1903. It will be observed that in six months the motor business of the Cincinnati Gas and Electric Company has increased 15 per cent, this gain being based on a very heavy initial load.

A central station may properly be regarded as a manu-

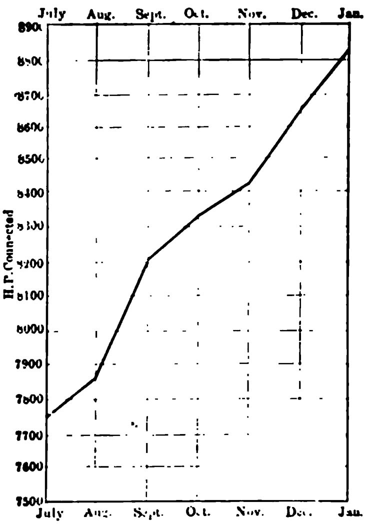


FIG. 5—INCREASE IN POWER SERVICE OF CINCINNATI GAS AND ELECTRIC COMPANY FOR SIX MONTHS ENDING JANUARY 1, 1904

facturing plant, and the same principles of operation apply to it as to any manufacturing institution. There must be the greatest possible simplification of output; production must be maintained on as nearly uniform basis as possible; the full productive capacity must be sold and all by-products utilized in every available way. Until a few years ago, electrical central stations were essentially lighting stations, and many of them came into existence to do municipal street lighting. To-day, however, conditions are materially changed. Companies are incorporated, and are giving service, as light, heat and power companies.

The Special Value of Motor Load to Small Stations

There has been a rapid increase in the number of small stations giving heating service. To such plants motor business is an absolute necessity, as otherwise steam necessary for heating service ceases to be a by-product, and the profitable conduct of a heating system by an electric-lighting plant becomes doubtful. Stations with auxiliary heating service can afford to offer extremely liberal inducements in the way of low rates for motor business, and the single-phase motor becomes an especially valuable adjunct under such conditions. There is a rapidly increasing number of instances where small

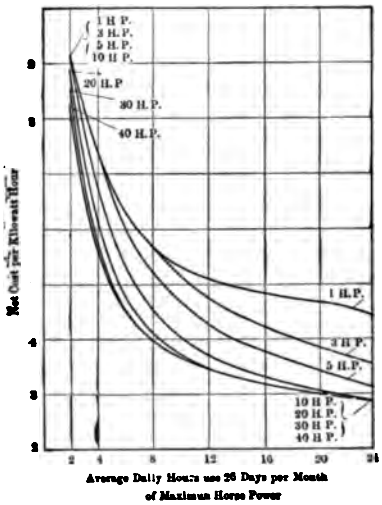


FIG. 6—ALTERNATING-CURRENT POWER RATE OF THE CHICAGO EDISON COMPANY

central stations, through the medium of single-phase motors, have been able to take on the municipal pumping service. A noted instance of this is at White Hall, Illinois, where the municipal pumping load is taken on immediately after the lighting load goes off at night. This load continues through the night and is cut off in time to avoid interference with the day motor service beginning at seven o'clock in the morning. White Hall is a town of 2500 population, and a single 100-kw generator is giving service to a motor load of something over 100 horse-power.

The Day Circuit as a Factor in the Building Up of Small Towns

It is a remarkable fact that the small central station giving day motor service is one of the strongest elements in the building up of a small town. Labor conditions in the large cities are forcing the establishment of small branch factories in outlying towns and villages. These branch factories are usually small institutions, individually considered, and it does not pay to operate power plants in them. Such factories gladly become power subscribers for the central station, and the ability to get this kind of service influences the location of many a plant of this character. Washington, Missouri, is a town of 3000 population about 50 miles west of St. Louis. The recent establishment of day service has immediately resulted in the location at that point of a branch shoe factory, of which the motor load is sufficient to pay the day operating expenses of the electric-lighting plant. There is immediate prospect of the location of several additional factories at Washington, and I am informed that the entire central-station aspect is so changed as to now justify the building of a new plant and the installation of larger generating capacity.

Power Rates for Single-phase Motor Service

Frequent inquiry is made as to the proper rates to be charged subscribers for motor service. As indicating the rates in force by several companies that are actively pushing the motor business, the schedules of the Chicago Edison Company (see Figure 6), the Peoria Gas and Electric Company, of Peoria, Illinois, and the Cincinnati Gas and Electric Company are appended.

This paper might be continued at some length, but the above will suffice as a basis for further discussion of the subject in open session.

ALTERNATING-CURRENT POWER RATES OF THE PEORIA GAS AND ELECTRIC COMPANY, PEORIA, ILLINOIS

0	to	100	kw-hours	consumed	during	1	month,	10	cents	per kw-hour
101	"	200	"	"	"	1	"	9	"	"
201	"	300	"	"	"	1	"	8	"	"
301	"	400	"	"	"	1	"	7	"	"
401	"	500	"	"	"	1	"	6	"	"
501	"	700	"	"	"	1	"	5	"	"
701	"	1000	"	"	"	1	"	4	"	"
1001	"	1500	"	"	"	1	"	3.5	"	"
1501	"	2000	"	"	"	1	"	3	"	"
Over		2000	"	"	"	1	"	2.8	"	"

Ten per cent discount on all bills paid before or on the tenth of the month.

ALTERNATING-CURRENT POWER RATES OF THE CINCINNATI GAS AND ELECTRIC COMPANY, CINCINNATI, OHIO

Base rate, 10 cents per 1000 watt-hours.

					Discount
On consumption in 1 month of	less than	100,000	watt-hours,	10 per cent
" "	100,000	to 200,000	"	20 "
" "	200,000	" 300,000	"	30 "
" "	300,000	" 400,000	"	40 "
" "	400 000	" 800,000	"	50 "
" "	over	800,000	"	60 "

Additional discount of five per cent for the payment of bills on or before the fifth day of the month following date of bill.

DISCUSSION

MR. HALLBERG: During the past year, while in the employ of the Cincinnati Gas and Electric Company, I had an opportunity to observe the application of the single-phase motors applied to polyphase systems of distribution. When I took charge of the Cincinnati plant the usual practice was to install three-phase motors for all purposes, excepting fan motors and small power motors, which were single-phase. After the first month or two several instances came under my observation where small three-phase motors—.75-hp to five-hp in capacity—were connected to the system, each requiring three transformers, two meters, one three-pole switch, and one three-pole cut-out. In addition to the above equipment for the motors, an additional transformer, meter, two-pole switch and two-pole cut-out had to be installed for the lighting service.

After some consideration it was decided that the smaller sizes of three-phase motors should be excluded from the system, in order to cut down fixed charges. It was found that the additional expense of service connections for polyphase motors amounted to anywhere from $25 to $125 more than for the single-phase motor, depending upon the size of the motor. A circular was then issued to all dealers in electric motors, informing them that on and after a certain date the Cincinnati Gas and Electric Company would not connect polyphase motors of smaller capacity than 15 horse-power to their alternating-current system, excluding elevator motors and motors for special purposes where the power was intermittent and of a constantly varying quantity, in which case three-phase motors could be used. The general practice is to run the three-phase lines or polyphase lines to a centre of distribution and then branch off

from that centre to the various points where the power is to be distributed, by means of two wires comprising one phase of the generated current. Under this condition the single-phase motor can be used to good advantage to take on customers who can not be supplied with three-phase current without a great deal of additional expense for running the extra wires to their premises.

The fact that the same transformer can be used for single-phase motor service, arc and incandescent lighting, simplifies the service construction; and the single-phase motor requires only one meter, and that of the simplest type.

The first cost of service for the single-phase motor is reduced to a minimum, as is also the cost of maintenance. The measurement of the power by one single-phase meter can be relied upon to be more correct than if a polyphase meter or two single-phase meters have to be used, as is the case for two-phase or three-phase motors. This latter point is important, especially if a number of motors are used in a factory and it is necessary to measure and record the power used in each department or by each motor, as referred to in Mr. Ferguson's discussion of the report on power distribution in factories. The wiring of a factory or building for single-phase motors can be done in the simplest manner and at a lower cost than if polyphase motors are used. All of these points should be considered when selecting alternating-current power motors.

THE PRESIDENT: We will now revert to a report that should have been considered at the first session, that of the committee on photometric values of arc lamps, Mr. Henry L. Doherty, chairman.

Mr. Doherty made the following report:

REPORT OF THE COMMITTEE FOR INVESTIGATING THE PHOTOMETRIC VALUES OF ARC LAMPS

Mr. President and Gentlemen: Owing to the illness of Dr. Matthews, we have not done any work during the past year. Dr. Matthews, because of hard application to his various duties, was incapacitated by trouble with his eyes. We expected him to be back at work again, but he has been unable to use his eyes, and the committee has done no work.

The committee was originally appointed as a committee on the photometric values of arc lamps at a time when the inclosed-arc lamp was making a great bid for popularity. There was some question about its illuminating value, its distribution being so different from that of the old direct-current lamp; and, its color being so different, it did not lend itself readily to photometric determinations. The committee worked on the direct-current arc lamp, on the alternating-current arc lamp, and on the alternating inclosed-arc lamp; but before it completed the work newer forms of lamps were in the field—the Nernst lamp, for instance. The committee also ascertained the photometric values of lamps other than electric lamps, such as the Welsbach lamp and the open-tip gas lamp.

Your committee, from the standpoint of the arc lamp, has done its work; perhaps not completely, but more completely than the average committee appointed for work of this kind in an association of this character, which is not entirely a technical association. There are other lamps constantly coming on the market, and your committee has worked for four or five years. Part of the expense of the work has been borne by the individual members of the committee, and nearly all the expense has been covered by individual subscriptions, thus relieving the association of any burden.

The committee is ready to continue the work or is ready to be discharged. It can continue the work at Purdue or elsewhere, and it is for the members to decide whether or not they want the work continued. There are new lamps, like the Cooper Hewitt lamp, coming on the market, but the photometric work on the lamps becomes difficult on account of the wide variation of the physical structure of the lamp and the different color effects that have been introduced into the newer lamps. It is a question whether or not the work is of sufficient importance for us to carry it on. At the time the committee was appointed there was a necessity for knowing the relative values of the old arc lamp and the newer arc lamp. We will bring the question up again at the executive meeting.

THE PRESIDENT: This matter will be laid on the table until the executive session to-night.

The next business on the programme is the report of the committee on analysis of flue gases, of which Mr. Doherty is also chairman.

REPORT OF COMMITTEE ON ANALYSIS OF FLUE GASES

MR. DOHERTY: This is a committee appointed two years ago for the analysis of flue gases. The committee had a report last year, but did not present it and intended to take further time for its consideration. We have a report here, in which, instead of treating flue-gas analysis, we have treated fuel economies; but owing to the absence of one member of our committee we have been unable to have all the members of the committee indorse the report that I have in my hand. We recommend at the conclusion of this report that this committee be discharged and a new committee be created—the members of the new committee to be so located geographically as to render easy conference with one another—to take up the work of fuel economy and all other work that would naturally be covered by such committee.

With regard to the present report, we are going to ask permission to put it into finished shape after the convention and send it out to the central stations in pamphlet form. The idea is to detail the simplest method for fuel economies in the ordinary plant and to set forth the work in such a way that the man without a technical education—and even a man who does not go about securing the details necessary for this work—may take up this paper and follow it. So we will issue, if we have your consent to do so, a pamphlet setting forth the best methods for securing fuel economies in the ordinary electric plant, covering the question of flue-gas analysis and the results that may be obtained in fuel economies by analyzing flue gases.

MR. DOTY: I move that the report be accepted and sent out to the members, and that the incoming administration be requested to appoint a committee on fuel economies.

(The motion was carried.)

THE PRESIDENT: The next number on the programme is the report entitled "Wrinkles," edited by Mr. Charles H. Williams, of Madison, Wisconsin. Mr. Williams, unfortunately, is not here, but Mr. Doherty will speak for him and for the paper.

MR. DOHERTY: President Edgar asked me to speak for this pamphlet because I suggested the adoption of this work by the association. I am not going into details. You have the *Wrinkles* and can study them. I am inclined to think that this

Wrinkle department will appeal more to the man who stays at home than to the man who comes to the convention—to the station men and the linemen. It is a scheme that was adopted a number of years ago by the Western Gas Association, and it proved so interesting and valuable to the gas fraternity that I recommended its adoption by the National Electric Light Association. There has not been an opportunity to edit these wrinkles as carefully this time as we hope to do in the future. The idea is to get an account of wrinkles that will suggest others to the members of the association and eventually to make this department of association work one of the greatest value to every officer and employee of the companies that are members of the association. The paper deals with many little things that are not important enough to merit treatment in an essay, not important enough to warrant patenting, and yet they are so useful that they could be used in many stations if there were some way of bringing them to the attention of all central-station men.

I am authorized to say for Mr. Williams that he can not undertake the work another year, so it will probably be in the hands of the incoming president to select another editor for this department. I think when you look over this pamphlet you will find that the work can be advantageously continued.

THE PRESIDENT: The pamphlet containing *Wrinkles* is before you. We shall be glad to have criticisms and suggestions regarding the work. Mr. Williams deserves our congratulations upon what he has done. I have looked over the report enough to know that there are a great many people in our business who will read it with great interest.

MR. DOTY: Before we proceed to the next paper, will it be in order to pass a vote of thanks to Mr. Williams, who will retire as editor of *Wrinkles*? Such work as that should not pass without some recognition by the association, in view of its magnitude.

THE PRESIDENT: A vote of that kind is always in order.

(The motion was put and carried.)

(The text of *Wrinkles* will be found in Volume II of the Proceedings.—EDITOR.)

THE PRESIDENT: The next business is the report of the editor of the *Question Box*. Will not Mr. Hartman say a word for his publication?

Mr. Hartman: I am not going to take up any more time than is necessary on the *Question Box*, but there are some few questions that have not been adequately answered and I should like your permission to bring them up for some little discussion.

The first one would have been a pertinent question in relation to the paper on gas engines, recently read. It is: "What is the percentage of repairs on gas engines to the total cost per kw-hour?" I hope there is some one that has had experience in operating gas engines in connection with electric-light plants who will answer that question.

The next one, to which no answer was received, is: "What is the average gas consumption per hp-hour of the average gas engine at one-quarter, one-half, three-quarters and full load?" That is another question that a good many people who are trying to buck gas engines would be glad to have answered.

Mr. Arthur Williams: The rating of gas engines using illuminating gas is usually 20 cubic feet per indicated horse-power, but in practice it is found that the consumption will vary from 30 to 40 feet; in some instances a higher consumption per indicated horse-power has been found.

Mr. Doty: In connection with the remark of the last speaker, I will say that it depends upon the load of the engine. If you rate the engine at full load, 20 feet per brake-horse-power is common practice.

There is one misapprehension that may exist in the minds of the delegates regarding the efficiency of gas appliances. I did not make reference yesterday, when the paper by Mr. Ayer was read, to the fact that I presumed it was intended for electric men. It certainly was not intended for gas men. The efficiency that he gave for gas appliances was 15 per cent. I presume that this figure was given for the encouragement of the use of electrical appliances. Certainly it was not intended for the discouragement of gas men or to discourage the introduction and use of gas appliances. Gas men know that the efficiency of a gas engine may reach 20 to 25 per cent, or even better. I know gas water heaters that when tested have shown an efficiency of 80 per cent or better. The efficiency of the boiling burners on a gas range when tested will show from 60 to 70 per cent or better. The efficiency of the oven burners when tested will show an efficiency of 50 per cent or better;

the reduction in the efficiency is due to the over-ventilation of the ovens. I hope the impression will not go out that gas appliances are so inefficient as to return but 15 per cent of the energy of the gas consumed. The electric business does not need that kind of stimulus.

Mr. Hartman: This question calls for gas consumption at one-quarter, one-half, three-quarters and full load.

Mr. Arthur Williams: The figures I gave relate to the average consumption of a gas engine working under average conditions, whether used for driving an electric-light plant or a factory. We do not care very much what it can do when working at its rated capacity; the question is, rather, what will it do under the normal loads, which vary from an average of three-quarters load downward, and the figures I have given relate to these conditions.

Mr. Doherty: I had occasion to look into that question and found a 65-page report presented at the May, 1902, meeting of the American Society of Mechanical Engineers, which gave an account of a number of tests under purely test conditions, steady load, and which represented the best obtainable economy. The figures, as I recollect them, were respectively 19 and 23 on full load.

Mr. Hartman: The following question is also asked: "What is considered a good income per kilowatt connected and per kilowatt demand load?"

Mr. Doty: I will say that $100 per year is considered a fair return, based upon the maximum demand per kw-hour; that is, if the maximum demand per kw-hour is 3000 kilowatts, it may be expected that the gross earnings of the electric company will reach $300,000 per year.

Mr. Tidd: In the matter of gas-engine tests, I had occasion some time ago to make a test on a gas engine running a 25-kw generator. It was running 25 per cent load factor for power and light, and on Philadelphia gas. We have to sell our current for a little over five cents per kw-hour, to compete—that is, to cover fuel alone. That does not include depreciation and interest on the investment, but fuel alone, gas at $1.00 a thousand. We used a gas meter, as well as having a calibrated wattmeter, and it amounted to a little over five cents per kw-hour on a 25 per cent load factor.

Mr. Whitfield: I wish to ask if some of the members can give some further information in answer to question No. 4: "What is the best way of cleaning racks in a water-power plant?"

There are several replies to that question, but most of the recommendations are to use long-handled rakes. We tried that at our plant, but found that at times it was impossible to keep the racks clean by that method. We had men at work continuously when the leaves were coming down, the men working as long as they could stand it and their places being taken by others when they must rest, but with continual work on the racks we found that sometimes they could not be kept open.

Mr. Richards: I have had some experience along that line in connection with the power-house at Mechanicsville built under my direction some five years ago. In the fall when the leaves came down, and in the spring when the rain brought down the dead leaves and rubbish, we had a great deal of trouble. At times it was necessary to have forty or fifty men on the racks to keep them clean. I took the question up with various companies operating water-power plants, and it seemed to be their experience that no mechanical device had been brought out that would do the work satisfactorily. At a paper-mill plant some miles above us a mechanical device was in use consisting of a sort of chain arrangement, similar to a stoker, and that was given a very thorough trial but did not prove a success. I think the only way to keep the racks clean is to have sufficient men on the racks. In one winter, for a few days, we took out from 50 to 100 tons of rubbish a day.

The President: If there is anyone who deserves a vote of thanks for work done for the association, it is Mr. Hartman. He has certainly devoted a great deal of time and effort to the production of his report.

Mr. Burnett: I was looking around the room to see some one better qualified than I to suggest such a motion. I think we must all admit that Mr. Hartman has presented to us a great mass of information that is of very unusual value, and I have great pleasure in moving a vote of thanks to him.

(The motion was put and carried.)

(The *Question Box* will be found in Volume II.—Editor.)

The President: Mr. Hancock's paper on underground construction has not been read to the convention. As a matter

of courtesy to the committee on award of the Doherty gold medal, I could not distribute it, although we took occasion to have it printed. It will now be distributed to the members. Mr. Hancock is of the opinion that it would be impossible to abstract it, and I agree with him. If there is no objection, it will be read by title and incorporated in the Proceedings the same as if read.

(The text of Mr. Hancock's paper will be found in Appendix A.—EDITOR.)

THE PRESIDENT: There was one other paper proposed for the convention, but owing to a misunderstanding it was delayed in printing, and it was not certain whether we could make room for it or not. It is by Mr. C. E. Skinner, of Pittsburg, and treats of oil for insulating purposes. We shall be glad to have Mr. Skinner present the paper.

Mr. Skinner presented an abstract of the following paper:

OIL FOR INSULATING PURPOSES

The use of oil as an insulating medium is so widespread and its applications are so numerous that a book would be required to cover the ground indicated by the heading of this paper if the subject were treated in detail in all its phases. Such a treatment would include the use of oil by itself as an insulating medium, as in transformer and switch work where the apparatus is completely immersed in the oil; oil used for saturating fibrous and other materials, as in cable work; drying oils—such as linseed—used for coating papers, cloths, *et cætera*, for the production of sheet insulation; the use of various kinds of oils as constituent parts of paints and varnishes that are intended for insulating purposes. This paper, however, will be confined to the first division of the subject, namely, oil as used for insulating transformers and oil switches.

Previous to 1890 there had been a limited use of oil for insulating transformers and induction coils, but this was confined to a few of the small sizes and low voltages. In 1891 the famous Frankfort-Lauffen transmission was accomplished by the aid of oil-insulated transformers, these transformers being wound for a line electromotive force of 30,000 volts. The Pomona, California, installation by the Westinghouse company followed in 1892, this being the first commercial installation of high-voltage transformers. The line electromotive force in this transmission was 10,000 volts, and the rated capacity of the individual transformers six kilowatts. Other installations followed rapidly, with constantly increasing voltage and capacity, until at the present time we have transmission lines operating at 55,000 volts and capacities of 3000 kilowatts in a single transformer. It was in connection with the Pomona installation that the subject of oil for insulating purposes was taken up by the writer and experiments carried on which led to the adoption of oil insulation for these transformers. This work, which was done in the year 1891, con-

sisted mainly of dielectric tests, which were made with apparatus capable of giving test voltages of 35,000 to 40,000 volts. At about this time the high frequency experiments of Tesla and Thompson attracted universal attention, these experiments being made possible by the use of oil-insulated induction coils and condensers.

At the present time the use of oil for insulating transformers and other similar apparatus has grown to such proportions that the production of this material, made for the special purpose, amounts to many hundreds of thousands of gallons per year. The increasing use of large oil switches has also added to the consumption of oil of the same general class.

In the early days various kinds of oil were proposed for the insulation of transformers, including rosin oil, linseed oil, cotton-seed oil, *et cætera*. It was soon demonstrated, however, that mineral oils obtained from petroleum products would be entirely satisfactory, and on account of their cheapness they were soon almost universally adopted for this purpose.

On account of the importance of this subject and on account of the recent discussion as to the fire risk of oil-insulated transformers, I have made it the chief object of this paper to describe the qualities of mineral oil suitable for use in oil-insulated transformers and to describe some of the tests that may be made to determine whether or not any given oil is suitable for the purpose. As mineral oil is almost universally used, tests for other kinds of oil are not considered. It should be stated at the outset that there is nothing mysterious in regard to the qualities of oil for ordinary transformer work and that comparatively simple tests may be made to show whether or not an oil has the necessary qualities.

Oil for Transformers—By transformer oil is meant an oil in which the transformer is completely immersed, forming a homogeneous insulation for those parts of the transformer that are not otherwise insulated and also adding to the insulation of such materials as may be permeated by the oil, such as the cotton covering of the wire used. Transformer oil also forms a cooling medium whose function is to receive the heat from the coils and core, where it is generated, and carry it to the outer and cooler parts of the transformer. Owing

to the fact that oil expands when heated, the hot oil rises and the colder oil from the sides of the containing tank flows in to take its place, thus setting up a circulation of the oil which continually cools the transformer.

Insulation—All oils—mineral, vegetable and animal—when pure, so far as I have been able to test them, are very good insulators. There is a wide difference in the insulating qualities of various mineral oils, but this difference seems to be more an index of the purity of the oil than an inherent difference due to variations in the chemical composition of the oil itself. By purity is meant freedom from acid, alkali, water or foreign matter of any kind. The method usually employed in determining the insulating value of an oil is to test its dielectric strength. Satisfactory insulation resistance measurements are difficult to make, and while showing something of the quality of the oil, are not of as much value as dielectric tests. As the actual values of the dielectric strength obtained vary greatly with the testing conditions, it is best to use a standard method and always follow this out carefully. Satisfactory comparative values may then be obtained and the general insulating value determined with sufficient exactness for all practical purposes.

The usual method of testing consists of immersing a spark gap in the oil, the gap being set at a known distance, and gradually raising the potential until rupture occurs. In making such tests the following points should be observed:

The spark-gap terminals should always be of the same shape and nicely polished, especially if the gap is quite small. Slight roughness or points on the testing terminals will change the apparent dielectric strength of the oil.

The gap should always be at the same depth in the oil. A variation in depth, consequently a variation of the pressure, will cause a variation in the tests. The apparent insulating strength increases with the pressure.

The testing voltage should always be applied in the same manner. It is preferable to fix the gap and apply an increasing voltage until breakdown occurs; or a constant voltage may be applied and the gap gradually shortened until the distance becomes such that rupture occurs. In the former method the voltage may be very gradually increased as may be done by

controlling the field of the generator, or it may be applied in steps, either with or without opening the circuits between steps; but for comparative purposes one method only should be used.

The time of application of the voltage should be as nearly as possible the same, especially the time consumed after the voltage reaches, say, 50 per cent of the dielectric strength. A longer time will give lower results, especially if the oil contains impurities that may "line up" between the testing terminals.

It is a good plan to make more than one test on each sample of oil, as the test value frequently increases with the first few tests, especially if the oil is well shaken after each test so as to mix thoroughly with the oil the carbon formed by the arc and not allow it to concentrate between the testing terminals. When so shaken it must be allowed to stand until free from air bubbles before another test is made. This increase in dielectric strength seems to be due to the drying effect or to the burning out of impurities in the oil. The best oils do not usually show much increase with repeated tests. When the oil becomes very black and dirty from repeated tests the dielectric strength drops rapidly.

The amount of oil used for each test should be the same in every case, especially if more than one break is made in each sample. It is obvious that the carbon formed by the burning of the oil will be disseminated through the oil, and that the results will depend in some measure upon the amount per cubic inch of oil. It follows from the above that if more than one test is to be made on a given sample, the amount of energy expended by the arc formed due to the rupture of the oil should be the same, as nearly as possible, for each break. It is best to limit this to a comparatively small amount by a fuse or circuit-breaker in the primary of the testing transformer, arranged to open the circuit on a comparatively small current. By using small currents the work of keeping the terminals clean is much facilitated.

The frequency and the electromotive force wave-form of the testing circuit should be kept the same in the successive tests. It was pointed out some years ago by Professor Elihu Thompson that oil is not as good an insulator for low as for

high frequencies. There is, however, little variation for commercial frequencies. It is well known that a pointed or saw-tooth electromotive force wave will break down insulation of all kinds more readily than a flat, smooth wave of the same square root of mean square electromotive force. The use of a resistance for varying the testing voltage is therefore very objectionable.

All vessels and apparatus used must be kept perfectly clean. A single fibre in the oil may reduce the dielectric strength greatly if it happens to "line up" between the terminals. A small amount of moisture, as will be shown later, is particularly objectionable, on account of the very great reduction that it may make in the insulating value of the oil.

It is best to allow the oil to stand a short time after pouring into the testing vessel, as the bubbles of air that are carried with the oil in pouring in, or due to the oil being agitated, will lower the apparent dielectric strength.

Insulation Test Apparatus—As a convenient method of testing, the author has devised a testing cup, which is shown in the accompanying illustration (Figure 1). This consists of a 200-cubic-centimetre graduated glass cylinder one and three-eighths inches inside diameter, with a hole drilled through the bottom through which the lower terminal is inserted. The testing terminals consist of half-inch diameter brass balls fastened to three-sixteenths-inch rods. The upper rod passes through a clamp which is connected to a micrometer screw actuated by a milled head. The lower terminal should fit in a socket, so that it may be readily removed for cleaning. The bottom of the cup is made oil-tight by the use of gaskets where the lower rod passes through the cup. An extension of the lower rod comes in contact with a spring set in the base of the stand to which the line terminal is connected by means of a convenient binding post. Stops are provided so that the oil vessel may always be placed in the same position. The upper rod may slide up and down easily when the clamping screw is free, or may be engaged with the micrometer screw at any point for adjusting the gap. All parts are therefore readily accessible for cleaning, and the zero point of the gap may be quickly adjusted for each test by allowing the upper rod to slide down so that the terminals

are in contact and then clamping to the micrometer screw. The apparatus is always filled to the 200-cubic-centimetre mark (requiring a little less than 200 cubic centimetres of oil for each test). The gap is adjusted to any convenient amount, usually 0.15 inch, and the electromotive force is raised gradually until breakdown occurs. After trying numerous forms of testing apparatus for this purpose, this method has

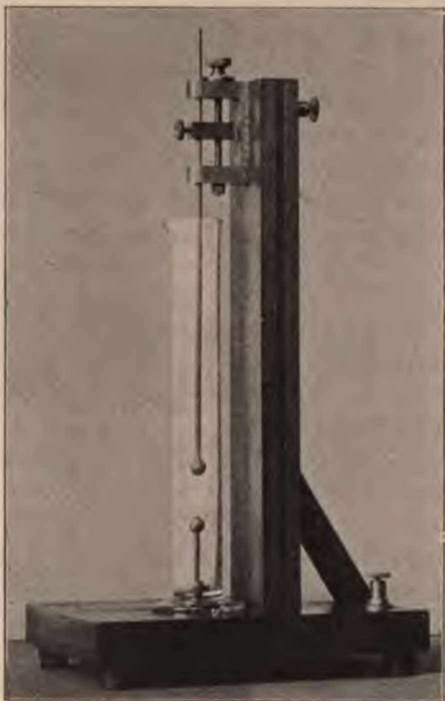


FIG. 1—OIL-TESTING CUP

been adopted as the most convenient, and it has the advantage of requiring a comparatively small amount of oil for each test.

Flash and Fire Test—By "flash test" is meant the temperature to which the oil must be heated in order to give off gases at such a rate as to form an explosive mixture with the surrounding air. By "fire test" is meant the temperature to

which the oil must be heated so that the oil itself will take fire and continue burning when a flame is applied to its surface. The general method of determining the flash and fire test of an oil is to heat the oil gradually, applying a test flame at intervals and noting the temperature at which a slight flash occurs on the surface when the testing flame is applied and the temperature at which the gases take fire and continue burning.

There are various types of apparatus on the market for making flash and fire tests. These may be divided in general into two classes—the open-cup method and the closed-cup method. For oils having a flashing point as high as ordinary transformer oil the open-cup method is preferable. The results reached by any method will depend largely on the taking of various precautions, which have been summarized by Gill in his "Handbook of Oil Analysis," as follows:

"1. *The Rate of Heating*—The faster the oil is heated, the lower will be the flash point, as more vapor is driven out.

"2. *Size and Depth of Cup*—From a large and shallow cup the liquid evaporates faster; hence the lower will be the flash point. The most constant results are obtained from a deep cup about half filled.

"3. *Quantity of Oil*—The larger the amount of oil, the more vapor will be driven out; hence the lower will be the flash point.

"4. *Distance of Testing Flame*—The nearer, or what amounts to the same thing, the larger the testing flame, the lower will be the flash point. A large flame may produce local superheating.

"5. *Point of Application of Testing Flame*—The flame should be applied at the edge, as the mixture of air and vapor is more complete; this is best effected by drawing the flame diametrically across the top of the cup. Dr. Dudley cites an instance in which the flash point obtained was considerably too high, owing to the fact that the testing flame was first applied to the centre of the cup.

"6. *The thermometers* used should be frequently compared with a standard instrument.

"7. *Drafts* should be carefully avoided."

Two general methods of heating the oil may be employed.

In the first the oil is placed in a vessel which is immersed in a second vessel filled with a very heavy oil, which transmits the heat to the oil to be tested. In the second method the heating flame is applied directly to the cup or to a sand bath on which the cup rests, the testing cup being protected from drafts. Both methods have their adherents, although the second one seems to be used more extensively for the high flash test oils. The author has found the New York State Board of Health tester, used with cover removed, very satisfactory. This tester is of the first class, using a bath in which the testing cup proper is placed.

There is a belief among many that oil as a body is very inflammable. Quite the reverse is true, as may be easily proven by any one without particular danger. A blow-torch may be turned directly upon the surface of a body of oil having a flash test of 175 degrees centigrade or more and the oil will not take fire for some time—in fact not until the burning or "fire-test" temperature of the oil is reached. A burning brand may be thrust into the oil and the fire is extinguished as effectually as if the brand were plunged into water. White-hot iron may be thrust into the oil and the iron is cooled, but the oil does not take fire provided the iron is plunged beneath the surface. The use of oil in oil switches proves that it is a very effective means of putting out the arc. When a fire does occur it may be easily put out if the supply of air can be shut off from the burning body of oil. It should be remembered, however, that material saturated with oil takes fire very readily, this being due to the fact that a small amount of the material, when coming in contact with the flame or spark, is heated to a temperature above the burning point of the oil and takes fire, the blaze thus started continuing to heat the surrounding material to the burning temperature. A precaution that should always be taken in the use of oil is to eliminate as far as possible all fibrous or porous materials that are not actually immersed in the oil and that may become saturated with it.

Since the above paragraph was written, in carrying out some tests on a very high-tension transformer, a spark passed between leads above the surface of the oil, igniting some fibrous material that surrounded the high-tension leads above

the oil level. This fire was readily extinguished by dipping oil from the tank and pouring on the blazing part.

In another instance a transformer was suspended above the oil tank for the purpose of making some examination with current on. Owing to a fault, the transformer, which was thoroughly oil-soaked, was set on fire and burned fiercely. It was dropped into the tank of oil and the fire was extinguished immediately.

Evaporation—Mineral oils begin to evaporate slightly at a temperature somewhat below their flashing point, and the evaporation is quite rapid at the flashing point and above. It is therefore essential that a transformer oil have a flash test sufficently high so that evaporation will not take place at the ordinary running temperature of the transformer. The evaporation test, if made at a temperature approximately 100 degrees centigrade, will also drive off any moisture that may be present in the oil. In the case of high flash test oils the evaporation test at 100 degrees centigrade may therefore show approximately the amount of moisture present in the oil. The evaporation test is not so necessary as the insulation and flash tests, but such test should be made occasionally on oil that is used for transformer work. A convenient method of making this test is to place a small amount of oil—usually approximately two grammes—in a small porcelain crucible and heat this over a water bath at a temperature of approximately 100 degrees centigrade for ten or twelve hours, then determine the percentage evaporation by loss in weight.

Moisture—The deteriorating effect of moisture on the insulating quality of an oil is very marked. As there are a great many ways in which the oil may take up moisture or moisture may be introduced into the oil, tests for moisture become very important. A very easy and satisfactory method of making test for moisture has been suggested to the author by a prominent oil chemist. This test consists in placing a small amount of oil in a cup, into which is plunged a piece of iron or other metal heated to a temperature just below a dull red heat. Any hissing or crackling noise indicates the presence of moisture. Another method of testing for moisture is to place a small amount of anhydrous copper sulphate in a test tube and then fill the tube with the oil to be tested.

After thoroughly shaking, a bluish tinge in the copper sulphate will indicate the presence of moisture in the oil.

It is difficult to determine the exact amount of moisture in oil when the amount is small, and this is not usually necessary, as it is sufficient to know qualitatively whether or not moisture is present. In making test for the effect of different percentages of moistures in the oil it was found necessary to dry the oil thoroughly, then introduce moisture

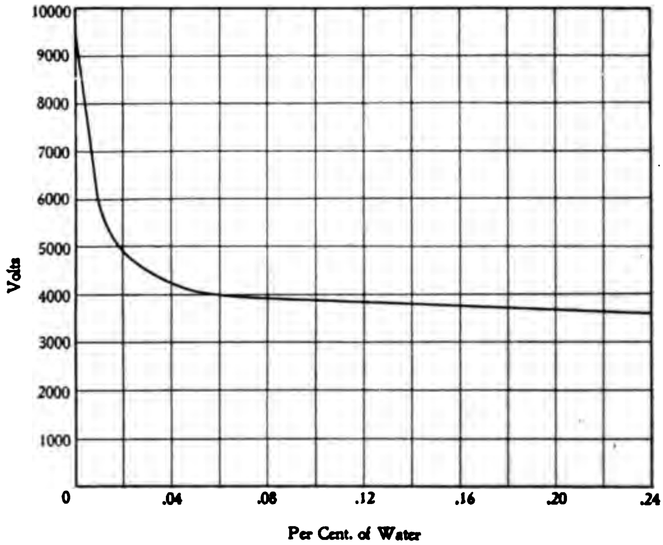


Fig. 2—Curve Showing Effect of Water in Oil.

Terminals........................	½ inch balls
Gap..............................	.075 inch
Frequency........................	133 cycles
Wave-form........................	Sine

in the form of water in minute quantities in a closed vessel and very thoroughly agitate the oil so as to disseminate the water through it. This method is not considered entirely reliable, but for testing purposes gave results so striking that a curve is given herewith showing some of the results obtained. It is considered that the form of the curve is correct, but it may be that the percentage amount of moisture present between the testing terminals is not entirely accurate. Check tests, however, gave close results. It will be seen from this

curve (Figure 2) that moisture introduced into the oil to the amount of .06 per cent reduced the dielectric strength of the oil to about 50 per cent of the original value when it was known to be free from moisture, and that there was very little further decrease in the dielectric strength due to increasing the amount of moisture introduced in the form of water.

Viscosity—The viscosity of an oil has been defined as the degree of its fluidity, or its internal friction. The viscosity is not a function of the specific gravity, but in general the less the specific gravity, the greater the fluidity of the oil. The viscosity of transformer oil, within limits, is not of great importance, although in general the more fluid the oil, the more rapid will be the circulation of the oil in the transformer tank and consequently the greater the cooling effect. The viscosity seems to bear no relation whatever to the insulation tests, the lighter oils—such as kerosene—showing as high, or higher, insulation tests than the very heavy oils. Tests for viscosity require special apparatus and special care in testing, and such tests are not usually considered necessary in connection with transformer oil. Directions for making such tests may be found in any text-book on lubricating oils.

Cold Test—The "cold test" of an oil is the temperature at which the oil will just flow. In ordinary transformer work this test is of no importance whatever, for the reason that the cold test of all oils that are suitable for transformer work is much lower than the normal operating temperature of the transformer, hence the oil is always in a fluid state when the transformer is in operation, and no harm whatever would result from the oil congealing in the transformer, inasmuch as there are no moving parts. Oil with a high cold test may not, however, be suitable for use in oil switches, which may be subject to intense cold, as the switch may "freeze up" due to the congealed oil and fail to operate on this account.

Color—For convenience in handling, it is desirable that a transformer oil be water-white in color, but this is not at all necessary, and as the production of a water-white oil usually means chemical treatment it is best to use a darker oil rather than to risk any chance of having traces of chemicals in the oil. Most oils get darker with continued use. The quality of the oil from an insulation standpoint does not apparently

suffer any change whatever due to darkening under the influence of temperature.

Sulphur Compounds—The action of sulphur on the insulation of transformer oil, while not yet thoroughly investigated, has shown in the few tests that the author has carried out to be very detrimental, and it is therefore considered best to eliminate sulphur compounds from transformer oil. Western oil is particularly liable to contain sulphur compounds, and therefore liable to give trouble from this cause. In some tests carried out some time ago the insulation resistance of a model transformer, after remaining at a very high value at high temperature for nearly a year, was lowered to the danger point in a few days by the introduction of a small amount of sulphur into the oil.

Deposit—In actual service it sometimes occurs that a brownish or black deposit is formed in the oil. Careful experiments have shown that this deposit is a phenomenon of temperature alone. This deposit is formed from the oil and from the insulating materials, such as varnishes, *et cætera*, which are used on the solid insulation of the transformer. This deposit is itself a good insulator, and the only harm done by such deposit is to impede the cooling of the transformer by lodging in the ventilating spaces and on the cooling coils of a water-cooled transformer. In very high-tension transformers there is also a tendency for this deposit, when it does occur, to line up at points where the stress is greatest. Such deposit does not necessarily mean a deterioration in the insulation of the oil or of the transformer, and occasional cleaning of the parts on which the deposit occurs is all that is necessary to keep the transformer in good condition. Where the transformer tops are partly open the deposit will contain dust and dirt which naturally get into the transformer case.

Action of Water-proofing Compounds—In many transformers water-proofing compounds are used, which may or may not be soluble in the oil in which the transformer is immersed. These water-proofing compounds are necessarily good insulators. The materials used may have either an asphalt, coal-tar or linseed-oil base. When asphalt or coal-tar base compounds are used they are always somewhat soluble in oil, especially when the oil is hot. Compounds having a linseed-oil base, when

thoroughly dry, are practically insoluble in mineral oil. When large quantities of water-proofing material, with asphalt or coal tar as a base, are used in transformers the compound resulting from the combination of the water-proofing material and the transformer oil may form a pasty mass, which will close up the ventilating spaces and consequently cause dangerous heating of the transformer due to lack of ventilation. From an insulation standpoint there is no objection to the water-proofing compound being dissolved out after the transformer is put in service, provided the design is such that the ventilating spaces, which are essential to the cooling of the transformer, are not filled up. Any compound that is soluble in mineral oil should not be depended upon for cementing parts of the transformer or for closing spaces when this compound may be dissolved out by the oil later. The linseed-oil compounds are water-proof in the sense that they will not allow water to pass through where there is an unbroken film; but they are not water-proof in the same way that asphalt and coal-tar base compounds are water-proof, that is, they are not "water-repellant." When transformers are treated with linseed-oil compounds more care must be taken to prevent the absorption of moisture than when the other classes of compounds are used.

It is to be hoped that the varnish chemists will be able to give us a compound that will have all the water-proofing qualities of the asphalt and coal-tar bases, but will be entirely insoluble in mineral oil.

Oil for Oil-Switch Work—The requirements of oil for oil-switch work are very similar to those of oil for transformers. As stated before, oil having a very low "cold test" may be desirable for use in switches that are intended for outdoor work; but as this use is comparatively small at the present time this point need not receive consideration in connection with the general application of oil to oil-switch work.

It has been stated above that the more fluid the oil for transformer work, the more rapid will be the cooling of the transformer, on account of the more rapid circulation of the oil in the transformer tank. In switch work a more viscous oil seems to give better results, possibly on account of the fact that it is not so easily displaced by the arc as is the lighter oil. Otherwise, the requirements throughout may be stated as

being exactly the same for both transformer and switch work, and it has been found possible to manufacture an oil that is entirely suitable for both purposes.

Specifications—In the foregoing the writer has endeavored to give some of the qualities necessary in a transformer and switch oil, and to describe some of the tests that will show whether or not the oil fulfills these conditions. In the following will be found a brief specification for such an oil, giving more in detail the exact requirements that the oil should fulfill:

(1) The oil should be a pure mineral oil obtained by fractional distillation of petroleum unmixed with any other substances and without subsequent chemical treatment.

(2) The flash test of the oil should not be less than 180 degrees centigrade (356 degrees Fahrenheit), and the burning test should not be less than 200 degrees centigrade (392 degrees Fahrenheit).

(3) The oil must not contain moisture, acid, alkali or sulphur compounds.

(4) The oil should not show an evaporation of more than 0.2 per cent when heated at 100 degrees centigrade for eight hours.

(5) It is desirable that the oil be as fluid as possible, and that the color be as light as can be obtained in an untreated oil.

In the above specifications no mention is made of the insulation test. This is omitted for two reasons: First, the manufacturers of oil suitable for transformer and switch work are unfortunately not equipped for making such tests, and the writer believes, as a fundamental principle, that no specification for material should include tests that can not be checked by both the manufacturer and the user of the material; second, an oil that meets the foregoing specifications should prove a first-class insulator. The writer has found it sufficient to insert a paragraph in the general specifications to the effect that careful insulation tests will be made on the oil, and if it falls below the standard in insulation the remainder of the specifications will be rigidly enforced. Thus far this specification has proved entirely satisfactory.

The specification proper should necessarily include specific

statement as to the methods that will be used in making the various tests. As already pointed out, the results may vary considerably, due to slight differences in test methods.

In addition to the specification the user should have the assurance that the oil is carefully made; that all containing vessels are clean and free from moisture; and that systematic tests are made on the finished material to see that it fulfills the conditions specified. He should also take the necessary precautions to see that no moisture is allowed to get into the oil after it is received by him. When oil is stored in barrels, the barrels should be kept under cover and water should not be allowed to stand on the heads, as it will often find its way through into the oil. Metal cans and drums are far more satisfactory for shipping and storing oil than barrels, for the reason that they can be made practically oil and water-tight, and there is therefore much less danger of the oil becoming wet during shipment and storage. The use of metal vessels also eliminates the glue which it is necessary to use in wooden barrels to make them tight. The transformer and transformer tanks should be thoroughly dried before the oil is put in, and every possible precaution should be taken to prevent water entering the transformer case after installation. In water-cooled transformers the cooling coils should be perfectly tight and the end of the cooling coils where the water enters should be lagged so as to prevent condensation of moisture due to this part of the coil being colder than the surrounding air.

When a good oil has been obtained from the manufacturer and the necessary precautions have been taken to insure that it is kept clean and free from moisture, it may be relied upon as one of the most satisfactory insulating mediums known.

DISCUSSION

MR. ABBOTT: I wish to ask Mr. Skinner if some oils have a greater affinity for moisture than others, and, if so, what are the characteristics of those oils that do or do not absorb moisture readily?

MR. SKINNER: I am afraid I can not answer that question positively. It has been very difficult to get at an exact measurement of the amount of moisture absorbed by any given oil. You can very easily prove its presence, but it is difficult to

prove how much is present, and I have no figures on different oils showing the relative amount absorbed.

MR. KIMBALL: I had two 300-light transformers in use two years, and at the end of that time they burned out and we found water at the bottom of the transformer case. Is there any way of testing transformer oil before putting it in?

MR. SKINNER: My paper gives a very simple method of testing oil for moisture. It consists in heating a piece of metal —copper or iron—to a temperature slightly below red heat and plunging it into a metal cup filled with oil. Any hissing noise indicates moisture. This test can be very readily checked by introducing a very minute quantity of moisture into oil that is known to be thoroughly free from moisture.

The presence of water at the bottom of the transformer tank is not due so much to the oil itself absorbing moisture as to condensation on the case and to actual leakage of water into the transformer. It should be remembered that when the oil has taken up the maximum amount of moisture that it will hold as moisture, the insulating properties of the oil are still fairly good—that is, for low-voltage work. For high-tension work it becomes a more serious matter. Burn-outs on low-voltage transformers, due to water, are more frequently caused by the water rising in the bottom of the tank so that it actually covers part of the coils.

MR. S. P. HUNT (Manchester, N. H.): I ask if the oil can be freed from water by heating by means of the transformer and its operation, or how is it best removed?

MR. SKINNER: The method usually followed by oil manufacturers themselves is to heat the oil to a temperature slightly above the boiling point of water.

MR. W. P. STEPHENS (Jackson, Mich.): I would ask Mr. Skinner regarding the evaporation of different oils in transformers. I have noticed in using different makes of transformers that in some the oil evaporates faster than in others. Is this caused by some oils being thinner than others, or is it caused by the transformers having different temperatures?

MR. SKINNER: Evaporation is a function of the flashing point of the oil and the temperature at which the transformer runs. Oil that is composed of a mixture of light and heavy oil may have a considerable evaporation. It will also have a

somewhat lower flashing point, so that the flashing point will be an indication of the point at which the evaporation begins. The flashing point may be described as the temperature at which the oil begins to give off sufficient gases to form an explosive mixture with the air. The evaporation begins at a temperature somewhat lower than the flashing point. The difference that you describe is due to a difference in the flashing point of the oil used or the difference in the temperature at which the transformer runs. Leakage from the case might also affect the apparent evaporation.

MR. EASTMAN: The test for the absorption of water, I believe, is the most important test to be made on transformer oils. I have tested oils that had a high dielectric strength when first received, but at the end of a year's service the dielectric strength would decrease to as low as half its original value. After boiling the oil the dielectric strength would be raised to its original value, showing that the decrease was due to absorption of moisture. Other transformer oils that have been in service for three or four years have shown but little absorption of moisture.

THE PRESIDENT: The hour for adjournment has now arrived. This evening Dr. F. A. C. Perrine, of Pittsfield, Massachusetts, will give an illustrated lecture on types of large water-power installation. We hope that all the members will be present at that time.

(The meeting adjourned until eight o'clock in the evening.)

SIXTH SESSION

The sixth session of the convention was held at eight o'clock on Thursday evening, and opened with the paper by Dr. Frederic A. C. Perrine, of Pittsfield, Massachusetts, on "Types of Large Water-Power Installations."

(Dr. Perrine's paper was profusely illustrated with stereopticon views, only a small number of which it has been practicable to reproduce.—EDITOR.)

TYPES OF LARGE WATER-POWER INSTALLATIONS

The development and use of the waterfall is a subject not only of vital industrial importance, but is also one of fascinating interest. Whatever charm the subject may have generally, it is much more worthy of attention and more picturesque when viewed from the standpoint of electrical development, which goes hand in hand with a preservation of the scenic effects, while affecting important social and industrial improvements. During the past 10 years you have been intimately concerned in this work, and it is fitting that you should know more of what has been accomplished by your fellow-workers. Young men have been the pioneers in this industry, and are yet to-day amongst its foremost workers. There has been no region too remote and no problem too difficult for their energies and ambition.

But before attempting to present to you the picturesque view of this work that is so intensely interesting from every side, it is well to stop and consider why we should be especially proud of the work that has been done, beyond the pride that we feel in winning success for ourselves and taking part in making nature do our work for us. Without thought, it is often the custom of some to consider and arraign the development for power purposes of the streams of our country as but a form of industrial vandalism. Such a belief or feeling can now be held only by the thoughtless and unobserving. John Ruskin during many years of his life bitterly arraigned the commercialism of his day, blaming mechanical inventiveness and progress for what he saw about him worthy of blame. He undoubtedly placed his finger on many sore spots in our day of progress, and about his teachings a school has developed which has accomplished much in spite of the fact that many of his fears and forebodings were groundless. The hideous characteristic of commercial growth about which he complained was but one of the accompaniments of new growth, for to-day we can not call modern commercial, industrial and mechanical progress old.

One hundred years is surely a short period in the world's history, and yet the birthday of the steam engine as applied

to manufacture dates back only to the spring of 1786. The first 50 years of the nineteenth century marked the introduction of all we know as manufacturing, while the last 50 years of that century developed practically all of the machinery we use to-day. Is it strange, then, that accompanying the birth of so many new ideas, and being engaged in their rapid development and introduction, those concerned with this work should use the machinery first in the crudest and most temporary manner, hesitating to build and plan as though in the belief that what they were doing was other than experimental?

With much of the crude mechanical application completed, we are now during the present century devoting our time and talents and using our opportunities for the development of the comfortable and artistic. Surely, no one who has for any period of time considered the products of manufacture can fail to notice and acknowledge this advance.

What I claim, then, is that the introduction of machinery and the use of new industrial ideas produce results not necessarily hideous, nor are they accompanied by a retrogression in taste or culture, but rather, in spite of what we have seen to condemn the development of the world's resources as we have seen them developed mechanically, are naturally devoted first to obtaining for all the comforts of life, and only after this object has been accomplished, to the attainment of culture, beauty and artistic surroundings.

In this the world differs in no one age from another. The primitive man—and we are never far from him—first supplies his needs, then his taste, and as often as possible indulges in a revel, but out of it all and because of all he does, develops character. Applying this view to the subject in hand causes us to see that if only we look about us we shall find in the first development of the waterfall our scenery destroyed, our streams polluted, and in place of the blessings of clear water and cozy nooks on the banks of flowing streams, the factory arising in unsanitary and unsafe conditions to supply our crying need for clothing to bear the winter's blasts.

But now, with all that accomplished, the electrician has come forward with his inventions in hand to remove the factory from the bank of the stream to a location where the health and comfort of the operative can be considered, and he has established the factory where there is a possibility of lifelong occupation with less of dirt and danger than ever could have been

THE LEANING TOWER OF THE CARQUINEZ SPAN, BY MEANS OF WHICH THE TRANSMISSION LINES ARE CARRIED ACROSS THE CARQUINEZ STRAITS

TRANSMISSION LINE FOR HIGH-VOLTAGE TRANSMISSION IN CALIFORNIA

accomplished in any other manner. Beyond the factory, too, the influence reaches far, for in the development of every horse-power of water energy made available by such means, there is at least 12 tons of coal less per year that it is necessary to mine for doing the world's work; by reason of each of the 1000-hp generators that the electrical companies are sending out every year in numbers there are 12,000 tons of coal less to be mined per year, and not for one year only, but for every year the machine continues in operation. The waterfall has been called the white coal mine, the miners, the stokers and the coal passers being the sun, the winds and the rain which continually replenish the river's source. Not only in its generation, but in its application, is the electrical development of the water-power important. It surely must be evident to all how important an element in the disintegration of the crowded and squalid portions of cities is the extension of electrical traction, and, further, the use of electrical power that may be distributed to great distances and applied in small quantities is rendering the small manufacturer more independent of the large one; an effect which in our country is only just becoming apparent and important, but which in some localities (as notably at Geneva, Switzerland) has had a marked effect on the character of trade, and has enabled the home-worker to continue in competition with the factory. Do not think that what has been said is an apology for electrical water-power development. On the contrary, it has been said in the hope of calling to your attention neglected facts that are about you and the importance of work that has been done in your midst.

The development, transmission and distribution of the power of the waterfall has resulted from the continuous study and work of the electrical discoverers, inventors, and engineers during a period of about 70 years, every year of which has been important to the result attained, though the last 10 years have produced the most striking of the practical results. During this period the advance has been so rapid as to astonish even the most sanguine and enthusiastic prophets of advancement.

The art of the electrician as we know it to-day began in 1832, when Faraday, working in his laboratory at Cambridge, England, discovered the principle of the production of electricity from magnetism, and laid the foundation for the invention of the dynamo-electric machine. In the year following, at Albany, New York, Joseph Henry discovered the principles that

are now embodied in the transformer, and with the foundations for the art thus laid, the inventions began.

Gradually the machinery was developed until suddenly and accidentally the reversibility of the dynamo was discovered at the Vienna Exposition of 1873, and the whole field of electric-motor working was opened up, for the reversed dynamo is the motor. Then began the study of the application of electricity as a motive power. In the early days attention was being given almost exclusively to lighting problems, and it was not until in the early eighties that the motor became a really important machine. About that time in California, in Switzerland, and in Northern Italy beginnings were made in the electrical use of the waterfall, but the present solution of the long-distance problem has been based upon the discoveries of Ferraris in the later eighties. The work of this Italian pointed out the manner in which the alternating motor could best be made, and how that beautifully simple generator, the alternator, which has no sparking commutator, and if necessary no moving wire, could be utilized for power purposes.

Furthermore, the experiments of Henry and his successors had shown how the pressure of the alternating current could be raised or lowered without moving apparatus, and this resulted finally in the development of the simple transformer.

The first American plant utilizing all of these elements was installed by the Stanley Company at Housatonic, the current being transmitted to the Monument Mills and Great Barrington. This was in 1893. From these small beginnings the art has rapidly advanced, the engineers and inventors working together and vieing with each other, till now there seems no problem too difficult or startling for them to attempt together.

The most startling and picturesque work has been carried out on the Pacific Coast, a land of no coal and little water, but in which the rivers flowing to the sea descend with most startling rapidity, permitting the development of great powers from insignificant streams. Over and through the central part of the state there runs a network of transmission lines fed by machinery designed and manufactured in Pittsfield. In this region many falls have been utilized, and the current is transmitted to great distances for the operation of lighting plants, railroads and mills.

Here the season of practically no rain is long and must

be guarded against by the storage of water in the mountain lakes of the high Sierras at elevations of from 6000 to 9000 feet. From these lakes the water falls into the bed of the rivers where it flows amongst the high mountains and through the deep cañons until it is caught and carried along the mountain sides through ditches and along the face of high precipices in timber flumes, until a point is reached where the difference of level between the ditch and the river is sufficient, and the site favorable, for the location of the power-house, when with a bold leap the water is carried in iron pipes down the mountain side to the power-house, where with immense force it plays on the buckets of the wheels in a stream of great power. These jets of water, spouting under pressures of from three to seven hundred pounds per square inch, seem now to have almost lost the character of ordinary water and to have become a different substance. Nothing built will resist the terrible tearing force they develop. The moving of mountains and the filling of rivers and harbors is a tale familiar to all from the stories of mining days, but even a knowledge of this does not enable one to realize the force so much as does the fact that these jets will wear away and tear apart riveted shells of boiler iron; a stream no larger than your smallest finger will pierce and kill a man as quickly almost as a shot from a gun; the skin will be stripped from the hand if laid for an instant along the side of the stream, and a stone or board thrown into it will rebound as from a surface of rubber, it being thrown many feet away. The scenes about these power-houses are of great beauty and are filled with many spectacular features. As one approaches one hears coming up the cañon a continuous humming sound as of many bees, for the machines that one sees here in the power-house once in operation are running continuously for weeks and months at a time. One can hardly realize that in this bright power-house, with no confusion or dirt, and little of the evidence of what one ordinarily associates with machinery, current is being generated for the operation of lights and cars and mills in cities many miles away, where annually the use of many thousands of tons of coal is being displaced.

In some ways the transmission of the current presents more startling feats of engineering than the generation of the current itself; poles, wires and insulators must be brought many miles into the mountains, distributed at inaccessible spots over a

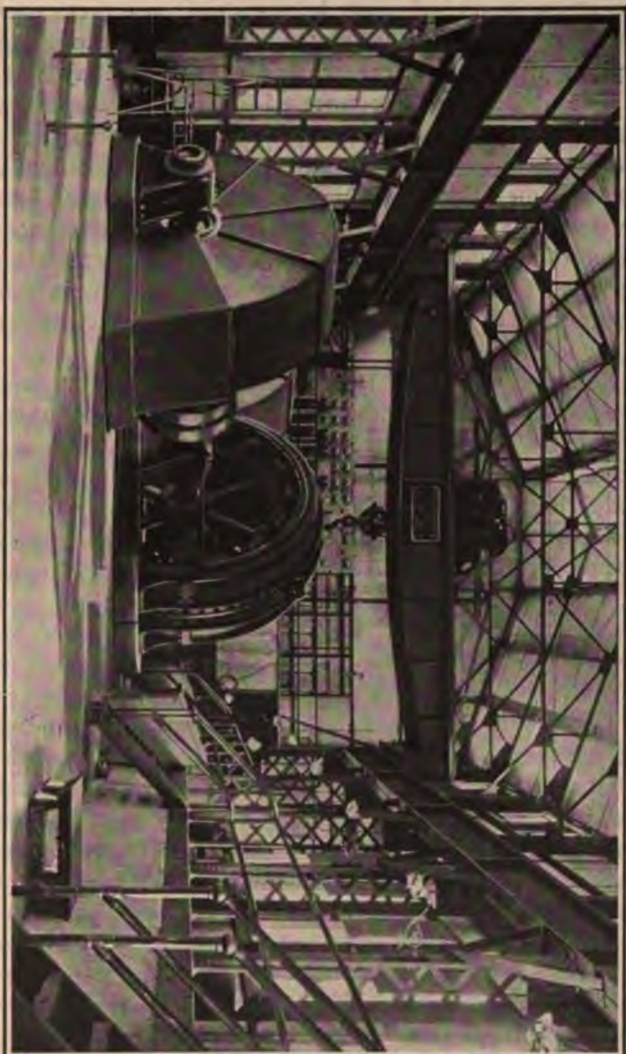
hostile country, and then after a right of way has been cleared through the forests the task of erection requires great skill and the ability to overcome obstacles of startling variety. At times the poles must be set in river beds by cementing to mounds of rock so that they will not be carried away during the spring floods; at other points the line must be swung across cañons, at times in spans exceeding one-quarter of a mile in length, and always stretching away over hills and valleys to the far distant city in a course as straight as possible. This is no haphazard work such as is often seen in the construction of the telegraph and telephone lines about us here, for the success of a transmission plant depends upon the permanence and continuity of its service, for the attainment of which the greatest precautions are taken in the clearing of the right of way and providing for a continuous patrol, inspecting and guarding the lines.

In the cities themselves simple substations are used for the distribution of the current, where often large amounts of power are made advisable without any accompaniment of dust or dirt and in a space much less than could avail for the steam engine doing a similar amount of work.

The pictures we have seen give one an idea of the typical high-head plant of the Pacific Coast where nothing is considered high head when the pressure is less than 100 pounds per square inch, representing a fall of water of about 200 feet, and from such heights the heads increase to a maximum of about 2000 feet, which represents almost the maximum in the developments accomplished up to the present time.

It will be interesting now to examine one that is almost the extreme in the opposite direction, and for that purpose we will take a glance over the plant at Sault Ste. Marie, Michigan. To be sure, the financial difficulties of the company developing this power have lately attracted much attention, but we are now discussing engineering and not finances. Of engineering of a high order there has been no lack at the Sault.

In carrying the water of Lake Superior around the St. Mary's Rapids to the power-house below them, where the small head of 18 feet is being utilized, one of the deepest and widest canals of the world has been built, 25 feet deep and 210 feet wide. This canal curves around the back of the town, emptying into St. Mary's River through the power-



The Interior of Electra. The Machines Are Placed Diagonally in Order to Minimize the Angle in the Pipes Bringing the Water Under 1500 Feet Head

house which has been built across the forebay at the end of the canal, the house itself being 1465 feet long, over a quarter of a mile. In this great power-house 80 small generators, each of 400 horse-power, are set, each being directly coupled to four water-wheels set without any flumes or pipes directly in the waters of the forebay itself.

The difficulties encountered in the development of this great power plant have been those of handling such a great volume of water, but, in spite of the great difficulties that have been met, the cost of the whole work has not been excessive, and when this plant is entirely completed there need be no fear of draught or flood, for from that greatest of storage reservoirs, Lake Superior, the flow at all seasons is remarkably constant and at all times sufficient for the generation of above 100,000 horse-power.

Some of the most beautiful natural scenery surrounding these power developments is to be found in our neighboring state of Mexico. There the characteristic plant is one with a diverting dam in the river, a large canal along the mountain side, and a water head at the wheels of from 80 to 100 feet. The work done in Mexico is of a surprisingly stable character; in every point of detail the extensive use of hand labor is made manifest, whether in dams, canals or power-houses, all of which is warranted by the fact that the fuel supply of Mexico is severely limited and the prices paid for power make large returns in revenue upon the investment in the power plants.

Let us not think that the development that has been made covers either the needs or opportunities of the present day or that the installations now being undertaken are simply those of which consideration has been previously suspended on account of more favorable opportunities of power development at other locations. On the contrary, amongst the developments now being studied are some of whose importance there has been an early appreciation. It is true that by reason of the advancement in electrical machinery for the development, transmission, and utilization of energy, there is now a possibility of larger stations than in any previous period of the world's history, and, furthermore, the question of accessibility and nearness to market is less important than heretofore; since there is now almost no limit to the size of development that may be successfully undertaken, though 10 years ago there was hardly a 5000-hp water-power plant in the country, and to-day

transmission distances up to 25 or 30 miles are considered short.

At present our engineers are engaged upon the studies for a plant of great magnitude on the Potomac river, at the very point where George Washington was engaged as a civil engineer before he entered Braddock's army.

The great falls of the Potomac operated flour mills before the revolution, and Benjamin F. Butler devoted much of his time and money toward securing control of all the power rights. leaving to his heirs a property that soon will be utilized in operating the lights and railroads of the city of Washington. The great falls of the Potomac river present engineering difficulties on account of the great fluctuations in the flow of the stream and on account of the peculiar fact that below the falls the river enters a narrow gorge about two miles in length where during flood periods the variation in the river's depth is as much as 60 feet. Only after continued study of the situation has a plan been evolved overcoming these difficulties by running a long canal and tunnel completely around the gorge and locating the power-house at a point where the river widens and the ebb and flow of the flood waters is not great.

I trust that I have here given you some slight idea of the problems our engineers have overcome, and have given you some insight into the fascinating side of the engineer's work, who always in doing his work is facing nature in all her moods—facile, fickle and wild—and who is ever benefiting those abroad as well as those at home and leaving behind him a work accom plished of benefit for all the future.

EXECUTIVE SESSION

President Edgar called the session to order at a quarter after nine o'clock in the evening, following the lecture by Dr. Perrine.

Mr. James I. Ayer, chairman of the committee on relations with kindred organizations, made a verbal report, and stated that the committee had arranged for the association to be represented at the International Electrical Congress to be held at St. Louis in September, 1904, by three members who would present papers. Mr. Ayer also stated that through the courtesy of the Association of Edison Illuminating Companies part of its space at the Louisiana Purchase Exposition had been set apart as the headquarters of the National Electric Light Association.

The report of the treasurer was read, as follows:

Report of the secretary and treasurer for the fiscal year ending December 31, 1903:

REPORT OF SECRETARY AND TREASURER

BOSTON, MASS., May 24, 1904.

1903. January 1, cash in bank	$8,501.74	
Petty cash in hands of assistant treasurer	150.23	
		$8,651.97
RECEIPTS DURING THE FISCAL YEAR		
Entrance fees active members, 1903	$350.00	
Dues active members, 1903	6,305.00	
Entrance fees active members, 1904	175.00	
Dues active members, 1904	140.00	
Dues associate members, 1902	60.00	
Dues associate members, 1903	1,600.00	
Dues associate members, 1904	20.00	
Contributions for the work of the committee for investigating the photometric values of arc lamps	462.50	
Sales of Reports of the Twenty-sixth Convention	200.00	
Receipts account municipal plants investigation	38.75	
Sale of badges	135.00	
Sums refunded	20.50	
Advertisements in Proceedings	1,375.00	
Sale of publications	332.25	$11,214.00
Total cash available during the year		$19,865.97

DISBURSEMENTS DURING THE FISCAL YEAR

Salary of former secretary and treasurer	$333.32	
Salary of assistant secretary and treasurer	1,791.62	
Office rent	503.35	
Office force	732.50	
Printing and stationery	564.03	
Traveling expenses	210.70	
Postage and telegrams	832.73	
Express and messengers	28.67	
Expenditures account Twenty-fifth Convention	1,342.03	
Expenditures account Twenty-sixth Convention	2,027.92	
Printing and expenses of publication	785.00	
Expenses district steam heating committee	58.75	
Dues, etc., refunded	18.50	
Office furniture	187.20	
Telephone rental and messengers	90.67	
Expenses account municipal fund	51.50	
Expenses account committee for investigating the photometric values of arc lamps	409.14	
Badges for the Twenty-sixth Convention	327.34	
Office sundries	97.20	
Total expenditures during the fiscal year		$10,392.17

CASH ON HAND DECEMBER 31, 1903

In bank	$9,323.80	
In hands of assistant treasurer	150.00	$9,473.80

ASSETS

Cash as per statement	$9,473.80
Office furniture	453.20
Total	$9,927.00

LIABILITIES

None except current bills.

STATEMENT OF FUND FOR EXPENSES OF COMMITTEE FOR INVESTIGATING THE PHOTOMETRIC VALUES OF ARC LAMPS

1903. January 1,	Balance on hand	$130.55
	Received during the year	462.50
		$593.05
	Disbursed during the year	409.14
1903. December 31,	Balance on hand	$183.91

MUNICIPAL PLANT INVESTIGATION FUND

1903. January 1,	Balance on hand	$2,772.20
	Received during the year	38.75
		$2,810.95
	Disbursed during the year	51.50
1903. December 31,	Balance on hand	$2,759.45

DISTRICT STEAM HEATING COMMITTEE FUND

1903, January 1,	Balance on hand	$250.00
	Disbursed during the year	58.75
1903, December 31,	Balance on hand	$191.25

STEAM TURBINE COMMITTEE

1903, December 31, Original appropriation intact.............. $1,000.00

Amount of cash on hand December 31, 1903, in general fund.... $5,339.19

Respectfully submitted,
ERNEST H. DAVIS,
Secretary and Treasurer.

Mr. H. H. Fairbanks, chairman of the finance committee, presented the following report:

REPORT OF FINANCE COMMITTEE

The finance committee begs to report that it has examined the books of the association and finds that the treasurer's report agrees with the amount as shown by the bank-book and vouchers that accompany it.

The committee begs to recommend that a professional auditor be employed to audit the accounts of the association annually, two weeks before the date of the annual convention, at the permanent office of the association, in New York city, and that his report be submitted as the report of the finance committee.

Respectfully submitted,

Committee, H. H. FAIRBANKS, Chairman.
W. S. BARSTOW,
E. F. PECK.

On motion, the report of the finance committee was accepted and the recommendations contained therein approved.

The report of the treasurer was then ordered to be accepted and approved.

It was recommended by the executive committee that the three papers to be read before the International Electrical Congress, to be held at St. Louis in September, 1904, with the names of the authors, be as follows: "American Meter Practice," by Mr. George Ross Green, of Philadelphia; "American Practice in High-Tension Line Construction and Operation," by Dr. Frederic A. C. Perrine, of Pittsfield, Massachusetts; and "The Pro-

tection and Control of Large High-Tension Distribution Systems," by Mr. George N. Eastman, of Chicago.

On motion of Mr. F. E. Smith, this recommendation of the executive committee was adopted.

On motion of Mr. Henry L. Doherty, the committee for investigating the photomteric values of arc lamps was discharged.

On motion of Mr. Henry L. Doherty, it was voted that the fund on hand contributed for municipal ownership investigation be maintained as at present, subject to conversion to the general fund at the will of the executive committee, as there was no probability of the same being needed for the purpose for which it was raised.

Action was taken on the report of the committee appointed to consider and report on proposed amendments to the constitution and by-laws, and the following amendments were approved by the association, to go into effect the first of January, 1905:

AMENDMENTS TO THE CONSTITUTION OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION AS PROPOSED AND RECOMMENDED BY THE SPECIAL COMMITTEE OF THE ASSOCIATION ON BY-LAWS FOR ACTION AT THE TWENTY-SEVENTH CONVENTION

Section 1 of Article III, on Membership, which reads as follows:

"Article III—Membership. Section 1. Members shall be divided into three classes—active, associate, and honorary. Active members only shall be entitled to vote, and shall be corporations or individuals engaged in the business of producing and supplying electricity for light, heat or power, for commercial and public use,"

be so amended as to read:

Article III—Membership. Section 1. Members shall be divided into five classes—Member companies, Members, Associate member companies, Associate members and Honorary members. Member companies only (Class A) shall be entitled to vote, and shall be private corporations or individuals engaged in the business of producing and supplying electricity for light, heat or power, for commercial or public use.

Section 2 of said Article III shall be a new section and shall read:

Section 2. Members shall be officers or employees of Member Companies, elected and continued only from year to year with the written consent of the Member Company with whom connected, and they shall be distinguished as Class B; and instructors and teachers of engineering and related sciences shall be eligible as members and shall be designated as Class C.

Members Class B shall have all the privileges of Member Companies Class A, except the right to vote, and to attend the executive sessions of the convention, but shall be allowed to attend such executive sessions upon obtaining the written consent of the Member Company Class A vouching for their membership.

Members Class C shall have all the privileges of Member Companies Class A, except the right to vote, to hold office, and to attend the executive sessions of the convention.

That present Section 2 be made Section 3, and shall read:

Section 3. Associate Member Companies shall be electricians, electrical or mechanical engineers, manufacturers—corporations or individuals—who are directly or indirectly interested in advancing the use of electricity. They shall have the right to attend all the meetings of the Association (except executive sessions), and to discuss papers read before the Association, and shall be known as Class D.

Associate Members shall be officers or employees of Associate Member Companies Class D elected and continued from year to year with the written consent of the Associate Member Company with whom connected. They shall have the right to attend all meetings of the Association (except executive sessions), and to discuss papers read before the Association; and they shall be designated Class E.

That present Section 3 be made Section 4, and shall read:

Section 4. Honorary members shall include those already elected as such, and such other persons as may be elected upon the unanimous recommendation of the executive committee and approved by a two-thirds vote of the Association.

That present Section 4 be made Section 5, and shall read:

Section 5. In case of a corporation the membership shall stand in the name of the company, and such company shall have

the right to be represented at any meeting of the Association by any of its officers or directors, or by its regularly employed manager or superintendent, and such representative may or may not be a Class B member.

That present Section 5, which reads:

"Section 5. No individual actively associated with a corporation holding an active membership shall become an active member in his own name unless he shall own and operate a central-station plant individually,"
be dropped.

Article VII—Dues, which reads as follows:

"Article VII—Dues. After January 1, 1903, all new active members shall pay an entrance fee of twenty-five dollars. The annual dues of active members in cities and towns of less than 20,000 population shall be ten dollars; the dues of active members in cities and towns of from 20,000 to 300,000 population shall be twenty-five dollars; and the dues of active members in cities and towns of over 300,000 population shall be fifty dollars, and dues of associate members shall be twenty dollars. These dues shall be payable in advance and shall cover the calendar year. Any member in arrears for one year's dues shall be dropped from the rolls, and if reinstated shall pay full dues for the time during which membership lapsed, or shall be required to pay again the entrance fee of twenty-five dollars.

"For the remainder of the year 1902, new members from towns of less than 20,000 population will be received in full membership upon payment of ten dollars dues,"
be so amended as to read:

Article VII—Dues. The entrance fee of Member Companies shall be twenty-five dollars.

The annual dues of Member Companies in cities and towns of less than 20,000 population shall be ten dollars; in cities or towns of from 20,000 to 300,000 population, twenty-five dollars; and in cities or towns of over 300,000 population, fifty dollars.

The initiation fee of Class B members shall be five dollars, and the annual dues shall be five dollars.

No initiation fee shall be paid by Class C members, and the annual dues shall be four dollars.

The initiation fee of Class D members shall be twenty-five dollars, and the annual dues shall be twenty dollars.

The initiation fee of Class E members shall be five dollars, and the annual dues shall be five dollars.

All dues shall be payable in advance, and shall cover the calendar year. Any member in arrears for one year's dues shall be dropped from the rolls, and if reinstated shall pay full dues for the time during which membership lapsed, or if required by the executive committee shall pay again the entrance fee of his class.

An amendment that voting by proxy be permitted only for the election of officers was voted down.

A suggestion by Mr. Samuel Scovil, of Cleveland, that the by-laws be so amended that the members of the nominating committee be elected at an executive meeting of the association, was discussed and then referred to the committee on amendments to by-laws, consisting of Mr. Henry L. Doherty, chairman, Mr. H. T. Hartman and Mr. George W. Brine, with instructions to report any desired amendments to the next convention for action by the association at the first executive session.

The committee on nominations presented the following report:

The nominating committee, after due consideration, begs to recommend the following nominations for the officers of this association for the ensuing year:

For president, Mr. Ernest H. Davis, of Williamsport, Pennsylvania.

For first vice-president, Mr. William H. Blood, Jr., of Seattle, Washington.

For second vice-president, Mr. Arthur Williams, of New York city.

For secretary, and treasurer, Mr. Dudley Farrand, of Newark, New Jersey.

For new members of the executive committee: Messrs. Samuel Scovil, of Cleveland; A. J. DeCamp, of Philadelphia, and W. F. White, of St. Louis.

Respectfully submitted,

Committee,
P. G. Gossler, Chairman,
D. P. Robinson,
Irvin Butterworth,
W. C. L. Eglin,
F. Ellwood Smith.

On motion of Mr. Ayer, the report of the committee was accepted, and the secretary was instructed to cast one ballot for the gentlemen named.

President Edgar appointed Mr. Ferguson and Mr. Doherty a committee to escort the newly-elected president to the chair.

PRESIDENT-ELECT DAVIS: Gentlemen of the convention, I am very much gratified at the unexpected action taken by the association, and I thank you for the honor that you have conferred upon me. Personally, I should have preferred that a man of greater experience in the art and science of electric lighting, and in the practical branches of the business, had been selected as your president. I am new to the business, but will say that, so far as my personal efforts are concerned, they shall be wholly and fully devoted to the success and best interests of the association. To achieve a full measure of success in the coming year, I must have, and shall certainly expect, the heartiest co-operation from all the members. I shall feel that I have the right, within reason, to get from every person connected with the association the information, papers and other data necessary to approximate, and if possible to exceed, the results of previous conventions. Small companies have not the same facilities for obtaining information of value to the association that the larger companies have, and the smaller companies—one of which I have the pleasure of representing—should appreciate, as I do, to the fullest extent the tremendous benefits that have been derived from the untiring and unselfish work of those representing the larger companies. I thank you very much, gentlemen, for this honor, and shall do my best to repay your confidence.

Captain Brophy, chairman of the committee on standard rules for electrical construction and operation, then presented the following report:

REPORT OF COMMITTEE ON STANDARD RULES FOR ELECTRICAL CONSTRUCTION AND OPERATION

To the President and Members of the National Electric Light Association:

GENTLEMEN: The committee on standard rules for electrical construction and operation takes great pleasure in announcing the fact that at the last meeting of the Underwriters' National Electric Association, held in New York in December, 1903, no

radical changes were made in the National Electrical Code, although many were proposed. Bearing in mind the radical departure attempted and in a measure accomplished by that association in attempting to assume the functions of the municipal authorities whose plain duty it is to regulate the location and construction of all classes of electrical lines located over or under the public streets, two members of your committee attended the meeting for the purpose of safeguarding the interests of the members of this association.

The only business of real importance to the members of this association was the report of the switch and cut-out committee, that is endeavoring to bring about a proper standard of inclosed fuse and fuse block, in order to prevent the improper fusing of branching and circuits. This, being a much desired end, meets with the approval of your committee.

Respectfully submitted,

Committee, { WILLIAM BROPHY, Chairman,
JAMES I. AYER,
LOUIS A. FERGUSON.

A discussion of the National Electrical Code followed the presentation of Captain Brophy's report, and upon motion of Mr. Scovil the matter was referred to the executive committee, with instructions to appoint a strong committee to take the matter up.

An invitation from the mayor of Niagara Falls was read, asking the association to hold its next meeting in that city.

Mr. E. F. Phillips, of Detroit, called attention to the merits of Detroit as a convention city.

Mr. DeCamp extended an invitation to the association to hold its next meeting in Philadelphia, promising to try to equal the entertainment provided for this convention by the Boston people.

Mr. Arthur Williams, on the part of the New York Edison company, expressed a desire to entertain the association in New York.

Mr. Tripp said, on behalf of the western members of the association, that in his opinion the next meeting should be held in the West.

MR. SCOVIL: I want to move that the hearty thanks of this

association and each member of it—and I know the ladies also desire to be included—be tendered to the New England entertainment committee, the New England Telephone Company, and to every contributor to the fund that has been provided for our entertainment. I know that I voice the sentiment of every individual who has had the opportunity to be in this famous old city during the past week when I say that we heartily thank you for what you have done for us. It has been beyond all precedent. I want to express for all concerned our very hearty appreciation of the great hospitality that we have received in your good city; and I know that in going away we shall carry with us very tender recollections of your very great kindness, and we only hope that we shall have an opportunity some day or other to come back and that we shall at that time be presided over by as competent an executive officer, as thorough a gentleman, and all-round good fellow, as Mr. Charles L. Edgar.

(The motion was put by the secretary and unanimously carried amid applause.)

Motion was made by Mr. Eglin that the incoming president appoint a committee of three to draft resolutions on the death of members who have died since the preceding convention.

(The motion was carried.)

Mr. Doherty, chairman of the committee on relations between manufacturers and central-station companies, reported that there was nothing of importance to present on the part of that committee.

On motion of Mr. Dow, Mr. Dusman's recommendation that inquiry blanks be sent to members in duplicate, printed in copying ink if possible, was adopted.

The convention then adjourned.

APPENDIX A

UNDERGROUND CONSTRUCTION

BY

W. P. HANCOCK

DIAGRAMS APPENDED

THE call of the Secretary of the Association, for a paper on Underground Construction, as per Mr. Doherty's previous request, that is to say, a paper "so complete and detailed, that any central station man who is forced to put his wires underground can do so by the guidance of such a paper," will no doubt be heeded to a large degree, and a great many men associated with underground construction will place the methods they choose to employ on record at this meeting; but the writer wishes to suggest that a "complete and detailed paper" as called for cannot be regarded as a short story, and therefore if there seems to be too much detail in this paper, I ask you to be lenient, for I have only intended to meet the requirements of the call.

PRELIMINARY SURVEY:

Assuming that the "central station man" has been forced to put his lines underground, or that he is to install a new system for either alternating or direct currents, the first thing he needs is a map of the district he wishes to cover; by a map I mean a survey such as one can generally find by applying to the city or town authorities; he will next consider what streets he can best use, after considering the load his system has or will have, the shortest distance available over which to transmit the load, his probable heavy points or centers of distribution, not for a moment losing sight of needs for future business, when considering the number of ducts which will form his conduit and the number and size of manholes he will need. If the district is located in a large city, he must, previous to deciding on any location, consult the street service plans of the city, and also those of other corporations, and find whether or not it is possible, at a reasonable cost, to sink his trenches, and locate his manholes, without interfering with the service of others, and he must especially keep in mind, that increasing distance, with a stated number of volts, means increasing loss in kilowatts, which reflects itself on the coal pile and, therefore, adds expense.

ACTUAL SURVEY:

Having settled in his own mind what he wants in the nature of lines, the "central station man" needs next an experienced and competent engineer, one to whom he can tell his needs and rely on for sound advice, and as soon as such assistance is secured, an actual survey should be promptly made on the proposed locations, by the usual method of measuring, and field book notes, and if, when the notes are complete, the conditions seem to indicate a reasonably good line without an excessive cost, the engineer should get his men at work on his notes, and produce therefrom the necessary plans, from which a prospective bidder on the work can see at a glance the location of the line, the distance between manholes, the cross section of the conduit, showing the number and size of ducts, the location, size inside, and probable depth of manholes, indicating also the thickness of walls and depth of concrete base, and whether walls are plain or shelved for cable supports, and also show the type of manhole cover.

Having completed his plans, traced them, and then secured the requisite number of blue-prints to submit to the city authorities and also to prospective bidders, he needs a set of specifications to give out with plans to the bidders, and if his engineer has had sufficient experience in this line of work, they can be furnished forthwith, and a set could be easily included with this paper, but are not, for the reason that I do not think the Association would appreciate them at this time, as it is well known that the specifications for this class of work are accessible if applied for at the office of most any large company.

RIGHT OF WAY:

The "central station man" having provided himself with the necessary data, he may now make his formal application for right of way on the one hand, while on the other he can send out his invitations to contractors for bids on his work. In the first instance I hope he is in good standing with "the powers that be," and in the second instance I hope he will send his invitations to bid to several contractors who have had experience in, and are competent to, construct conduit lines for electrical service, and not assume that a few laborers and a brick mason are all that is needed.

PLACING CONTRACT:

Assuming that right of way has been secured, and that bids have arrived in the meantime, you are now ready to place a contract for

your work and your engineer should then be called on for advice in this important matter; he should with you look over the bids, for while the specifications and plans submitted are alike, it does not necessarily follow that the lowest bidder should do the work. His responsibility, financial and moral, should be considered. The question of his experience and ability to carry on work of this type in crowded streets without excessive complaint from abuttors, and especially, your own customers' interests should be looked after thoroughly, and additional to this, he should give you a bond to indemnify your company for accidents which may occur on his work; another bond, to guarantee his workmanship and material for a period not to exceed five years; and another one, if required, to keep the surface of the streets through which he has operated in such a condition as is required by your city officials, for a period not to exceed one year.

One more point as to the contractor and the specifications. Make the latter iron-clad if you choose; make them, if you will, so that they stand practically for the interest of your company alone, but after you do that, use discretion, for if you do a great deal of this type of work, you will find that to be reasonable and fair with a contractor who is doing your work, and who encounters difficulties in its progress that either he or you did not even imagine existed, will in the end be an advantage to you rather than otherwise; and bear in mind, that he is open to criticism from all the people who are on the streets and all of the companies or individuals who have property under them, and of course, being a "central station man," you will at least sympathize more or less by reason of having had troubles of your own.

MATERIAL AND LABOR:

Whether you intend to build your lines yourself or have them built by contract, there will be material and labor used, and it should be of the best of its kind in either case, and for the reason that a first-class conduit installed is good for all time, so far as wear is concerned, and if the material has been of the best and the workmanship all that it should be, the repair and renewal charges will be low enough to please you at the end of every month in the year.

In taking up the matter of material and labor I shall use some figures which will closely approximate the correct, but I am using them for illustrative purposes only, and I will ask you to kindly consider that they are given for that end.

Then the material you will need follows: —

First, a clay duct that is suited to your conditions. If your streets

are congested under the surface use a short length single duct; if the work is in a suburban district use a clay duct constructed in multiple, and in either case make a careful selection and provide yourself with goods made from the right kind of clay, and by that I mean a clay that when it is in its finished state and ready for use is as nearly non-absorbent as possible. For the concrete you will need a grade which is not of excessive cost, but it should be made sufficiently strong so that four inches of it will form a suitable foundation for your conduit, and you will with the same grade surround the two sides and the top of the conduit with a thickness of three inches. The concrete should be composed of a five-part mixture as follows: One part good quality Rosendale cement, two parts crushed stone, two parts sand; and with the conduit protected on all sides with this mixture, well set, there will be little danger of its ever being disturbed or injured in any way by other underground work which may be installed in the future in close proximity to your lines.

You need mortar to lay your ducts, and to build the manholes, and Rosendale cement one part, and two parts sand, will make a strong mortar for these purposes; in fact there are many who would make this mortar of one part cement and three parts sand, but from actual experience I prefer the former mixture.

You will need a good quality of spruce boards one inch thick for the side boards on either side of the trench, in order to form the concrete to the conduit, and not waste the concrete material, and you will also need the lumber to cover the top of your conduit, after the three inches of concrete has been placed over the ducts, but this top layer of spruce should be two inches thick. Many prefer to use creosoted plank, or so called kyanized lumber, but in my opinion the extra cost of this material over that of plain two-inch spruce plank is money wasted, for as a matter of fact this protection is for two purposes only, first to protect the top concrete until it is set solid, and after that its only function is to serve as a signal to future excavators, that they are sinking over some sort of construction, the location of which they have failed to note in their plans.

Your bricks for the manholes, or perhaps handholes, or both, should be a good quality of hard burned sewer brick so called. The frame-work for the top of the manhole, which will support the roof and manhole frame and cover, should, in all ordinary manholes, consist of steel rails; second-hand sixty-pound rails will answer the purpose, unless the traffic is of an unusually heavy nature in the district. In a manhole five by five feet inside you will need eight pieces of the above

material. Manhole castings may be of the heavy sewer type, or of the double cover type, depending on the type of lines which will operate through the manholes, and also whether or not transformers are to be placed therein. Additional material in the form of tools, lanterns, barriers, flags and lumber for crossings and sheeting the trench when necessary, will be needed if you do the work with stock and labor from your own company; but I will suggest that you will have less difficulty, less book-keeping, and have just as good lines, if you employ the right kind of a contractor.

Assuming you wish to furnish your own labor, you already have secured the services of a good engineer, who, having assisted you to lay out your lines, will in general oversee the work, providing himself with such assistants as he may consider necessary, which will be dependent on how much ground you want to open at one time, whether or not the total work is in one locality or scattered, whether the season is early and you have reasonable time ahead, previous to cold weather, to complete the work, and whether or not the locations of the lines are in streets difficult to open on account of traffic, and your engineer will give his instructions to such assistants, and these instructions will be based on the terms and conditions of the plans, specifications, and contract, and he will deputize them and vest them with proper authority to represent him on their several locations, and see that the work is carried on in strict accordance with the lines, grades and locations, as shown by the plans; and the contractor should be officially notified by the engineer that such assistants will take charge of certain sections, and that their orders are to be followed as fully as if they were given by the engineer himself. The assistants in each and every case should not only perform the duties as heretofore laid down, but should carefully watch the progress of excavation, and in case of obstructions being encountered should use their best efforts to overcome them, and if possible keep the route as originally laid down intact; as for instance, it may happen that service pipes of some corporation may interfere with the sinking of the trench, or the location of a manhole, and if, for instance, it be a water or gas main, and it becomes necessary to offset the original line, the assistant must look into the feasibility of such a matter, take his measurements carefully, and find out whether or not there is the requisite space without fouling another service, and if it is a case where the trench must sink deeper, then care should be exercised on the matter of grades, so that the section will pitch both ways to the manholes on its terminals, and thereby drain itself to the sewer connection which is in the manholes. If obstructions appear in the

manhole location, and are not far below the surface, then in most cases these can be avoided by setting the manhole frame on one side, or perhaps on one corner of the manhole, and if the pipes occur on both sides of the location, roof the manhole partially, on each side, and under the obstructions, and build what we term a chimney up to a point of proper height, and between the pipes, and then set the frames on the chimney.

If pipes of any kind appear in the manhole location deep enough to interfere with working on cables, or within the enclosure occupied by ducts and cables, they should be removed, for a gas or water main in an electric service manhole in these days is a menace to life and property. I am aware, by actual observation, that they do occur in a great many manholes in the largest cities, but that fact does not warrant such practice nor lessen the danger. It should be the duty of the assistant engineer to at once take steps to rid the location of the pipe or pipes, and if, after diligence and patience have been exercised in that direction, it has been found to be impossible to have them removed, then the location of the manhole should be changed, even if the duct line is to be deviated from its original route thereby, and in case this is done and the line offset, make sure that the curve is easy, and that no reverse curves appear. It will be well to remember at this point, that the contractor will claim extras for re-locating manholes, or offset lines, but it is the business of the assistant engineer at that time to follow the specifications, for it must be remembered that the plans of the line have been laid down after having exhausted all obtainable means of information, and that they were submitted in good faith to the contractor, also that specifications have been written which contain an obstruction clause, and it is assumed that the bidder had read them before he sent his figures to the company; but as I have said previously in this paper with reference to writing specifications, this is one of the occasions when the engineer for the company should be discreet, and consult higher authority than he is vested with, on the question of an extra, if in his own mind such a thing is fairly due the contractor.

One more point with reference to the duties of the assistant engineer: it should be his most imperative duty to take notes as his section of work progresses, in such volume, and with such accuracy, by actual measurement, to enable him to absolutely correct the original plans as laid down, provided re-locations have been made to avoid obstructions, lines offset, or if anything of that nature has occurred; and it is all to the advantage of the company that this matter is carried

out in that manner, and the writer understands that fact from actual experience. A record also of the manholes should be accurately kept and the record should give the number of the manhole, the street, and the street number, nearest to its location, and this, with a correction once in six months, in case the names of streets or street numbers change, will suffice for a record that will become invaluable in case of fire troubles or troubles on lines, and for various other purposes.

Additional to your assistants to your engineer you need a general foreman, and you cannot afford to have a man in that position that is not acquainted with this line of work. Under this man, for every thirty-five men you have on the trench at work, you will need a sub-foreman, provided the streets to be opened are in a city of much traffic.

Upon this general foreman you will need to place a great deal of dependence, for he is the man who can make your pay-roll appear heavy for the amount of work performed, if he has not had experience in this line of work, and if he has had experience and has not the "steam" in his makeup, the pay-roll will then reflect the fault. He must instruct his sub-foreman as to what he expects to do in a day in certain kinds of ground, and furthermore he must see that he gets it. He must not run behind for material, but order it in time to keep the work moving, and when his excavated material appears on the street in too great quantity, he must have his teams there in time to get it away, and not wait until the city officials drop in on him or your company, with an ultimatum with reference to obstructing the street. He must be able to watch his work and the men who do it from the beginning of the day until its end, and be able to observe the laggards and cut them out. He must watch the weather, and not let a rainstorm overtake him to the detriment of the abuttors' interests, and especially so if they are customers or prospective customers; he must observe the rule of cities, that bridges over all openings necessarily crossed by foot passengers must be maintained at all times during the progress of the work, and that such bridges must have hand rails. The same applies for openings nearer the center of the street, where the crossing of heavy teams and fire apparatus is concerned.

He must see that necessary barriers are in place, in case he has been given permission to close an opening to a street, and see that the total openings made by his men are flagged at all times by day, and lighted with lanterns from sunset to sunrise.

BASE OF ESTIMATES

ILLUSTRATION:

Having seen what you need in the nature of material and labor we will now look into the matter of how much you need of each and its approximate cost, and in order to better illustrate we will assume that we wish to install a conduit of fifteen ducts cross section, with four manholes five feet square inside, plain, seven feet deep under the cover, then —

Total length of line, 1,500 feet.

Number of manholes, 4.

Size of manholes, 5' 0" × 5' 0" × 7' 0" × 8" walls, plain.

Width of trench, 32½".

Depth of trench, 64½".

Depth of cover plank to surface, 42".

Paving figured at an average cost of all granite block paving, including four types, average, per yard, $1.44.

Cubic feet of excavation, per linear foot, 14.39.

Cubic feet concrete, per linear foot, 1.93.

Length of line less manhole space, 1,480 feet.

Plate No. 1 will show a manhole diagram in both plan and section, and Plate No. 2 will show a cross section of the lines.

EXCAVATION AND BACKFILLING:

Cost is based on the actual measurements of the cross-section drawing of the conduit for dimensions, and $.0278 per cubic foot, and this figure is based on labor at $1.50 per day of ten hours and excavating and backfilling two cubic yards per day per man, and therefore, as the trench in question contains 14.39 cubic feet per linear foot, the cost per foot in length for this item will be $.0266 per duct foot or $.3990 per conduit foot.

LUMBER:

Cost of lumber, which is needed next, is based on a price of $15.00 per thousand feet 1 inch in thickness, for a fair grade of spruce. The dimensions are taken from the cross-section drawing. Then the cost of the lumber per square foot would be $.015 and twenty per cent has been added for cleats and waste. We also know by experience, that one man in one day of ten hours at a cost of $2.00 will cut and place the lumber for 500 feet of three-duct conduit, or at a cost of $.00061 per square foot, or $.0004 per duct foot; and therefore, on that basis, the

lumber for one linear foot of the trench in question would cost \$.1575, and labor for cutting and placing the same would cost \$.0060.

MIX AND PLACE THE CONCRETE:

Cost of concrete is based on actual dimensions shown on cross-section drawing, and then five per cent is added to our estimate for wasted material and this percentage is ample for the purpose; and now to illustrate we will find the material needed, the proportions of each we need, and what it costs, basing the cost of material on Rosendale cement at \$1.15 per barrel, crushed stone at \$.086 per cubic foot, sand at \$.05 per cubic foot. We need, however, something to measure the material with, that is convenient. I have used a cement barrel on most work for that purpose, but of course, if you wish, you can have a standard receptacle made for that purpose. If you try the experiment on a dozen barrels you will find that each will contain very near 3.5 cubic feet of dry material, and in this section of the country the tip carts, so called, which we use for hauling sand, earth and stone, will contain 35.1 cubic feet, or about 1.3 cubic yards. Now, with these two items, we have a means of measurement which laborers can understand and use, and the means is always at hand. Then if we decided to use the barrel, we would say .13 of a yard or 3.51 cubic feet of dry material is what it will contain, and our concrete is to be a five-part mixture, and if the laborers were mixing they would simply turn down on the mixing ground, or concrete board, two barrels of sand, and over this material they would spread two barrels of crushed stone, and last spread one barrel of cement over the sand and stone, and then settle the material together dry, and then, when wet and thoroughly mixed, they would have what is called on the work a batch of concrete; but what we want to get at is the cost of a yard of concrete. As a matter of fact we know by actual measurement with the material on the ground, that the shrinkage of the material when wet is thirty per cent; in other words, if there was no shrinkage we should need for a yard of concrete 5.4 cubic feet of cement, 10.8 cubic feet of stone, 10.8 cubic feet of sand. Now we know that the above is only seventy per cent of the stock needed to give us one cubic yard of finished concrete on account of the shrinkage. Therefore, we must add enough of the dry material to make up the remaining thirty per cent.

Then for the cement we shall need : $\frac{5.4}{.7} = 7.7$ cubic feet; for the sand, $\frac{10.8}{.7} = 15.4$ cubic feet; for the stone, $\frac{10.8}{.7} = 15.4$, or a total 38.5,

cubic feet of dry material, which divided by 3.5 cubic feet, which is the contents of our measure, gives us eleven barrels, and the same result will obtain if we use yards instead of cubic feet, or use the barrel absolutely, as follows:

We know the measure has a cubic contents of .13 of a yard when filled with dry material, and as it shrinks 30 per cent when wet the contents would be $.13 \times .70 = .091$ of a cubic yard; then, $\frac{1000}{.091} = 11$ is the number of barrels of dry stock we shall require to obtain a yard of concrete ready for use; then,

$\frac{11}{5} = 2.2$ barrels Rosendale = one part cement at \$1.15	\$2.53
$\frac{11}{5} = 2.2 \times 2 = 4.4$ barrels = two parts stone at .086 cubic ft.	1.32
$\frac{11}{5} = 2.2 \times 2 = 4.4$ barrels = two parts sand at \$0.05 cubic ft.	77
Total 5 parts	\$4.62
Add five per cent for wasted material	23
Total cost stock for one yard concrete	\$4.85

or eighteen cents per cubic foot.

As we know that our 15-duct conduit will require 1.93 cubic feet per conduit foot, then 1.93×18 = cost of concrete per conduit foot = \$.3465 and per duct foot \$.0231. By actual test, and several of them, we know that six laborers will mix the stock for one yard of concrete in twenty minutes, and the same men will in twenty minutes more place the concrete in the trench, and with labor at \$1.50 per day of ten hours the cost would amount to sixty cents for placing one yard of concrete in the trench or a total cost of \$.0029 per duct foot, and the labor to mix and place the concrete per conduit foot would cost \$.0435.

MIX AND PLACE THE MORTAR:

Cost of mortar is based on same prices for cement and sand as in the concrete, and since .13 of a yard is the contents of a barrel, we shall need eight barrels of material for a yard of mortar.

$\frac{8}{3} = 2.66 \times 2 = 5.34$ sand = 2 parts at \$.05 cubic foot	93
$\frac{8}{3} = 2.66$ barrels cement = 1 part at \$1.15	\$3.05
Total cost material, 3 parts	\$3.98

I have found by experience that a mason's helper at \$2.50 per day of ten hours will mix and deliver to the mason in the trench, or the duct layer, one yard of mortar, and that one yard of mortar will lay 1500 feet of duct, same having beveled edges and a length of 18", and an ample provision for wasted material is also considered in the amount of mortar stated for 1,500 duct feet.

The cost of mortar per duct foot would be \$.0026 and the cost of mortar for our 15-duct line would be per conduit foot \$.0390; cost of labor to mix and place mortar would be per duct foot \$.0016; and per conduit foot for 15-duct line would be \$.0240.

DUCTS LAID:

Cost is based on the ducts being laid beside the trench at \$.0502 per duct foot, and this includes teaming from the cars to the trench at a cost of \$.75 per ton. (The weight of an 18-inch length of 3-inch duct is 13 pounds or nearly 9 pounds per foot.) The ducts, then, for our 15-duct line would cost $15 \times .0502 = \$.7530$ per conduit foot; cost of labor to lay ducts is based on mason's labor at \$4.00 per day of ten hours, and a helper at \$2.00 per day of ten hours, or a total of \$6.00, and these two men will lay an average of 1,500 feet or 1,000 lengths per day; therefore, the cost of labor per duct foot will be $\frac{6.00}{1,500} = \$.0040$; and the cost of a conduit foot in our 15-duct line will be $\$.0040 \times 15 = \$.0600$.

PAVING:

Cost of paving is based on actual bids submitted by Boston contractors for replacing paving, no new blocks being furnished by the contractor to make up any deficiency or loss by breakage of blocks. The price which I shall designate as the average cost of paving is for stone block paving only, and does not include asphalt nor wood paving. Our bids have come along as follows:

Replacing stone blocks on 6-inch concrete base, pitch and pebble joints	\$2.00	per	yd.
Replacing stone blocks on 6-inch concrete base, Portland cement joints	1.85	"	"
Replacing stone blocks on 6-inch concrete base, gravel joints	1.40	"	"
Replacing stone blocks on gravel, gravel joints........	.50	"	"

making the average cost approximately \$1.44 per square yard for this

work. (If the surface is of asphalt the cost of replacing will be $3.50 per square yard or 39 cents per foot.) For the cost of repaving our street over our 15 duct line, we will use the average price per yard, and we know that the net width of the trench is 32¼ inches, and we will add to this a margin of 12 inches on each side, thus making the width to estimate from, 56 inches approximately; and if we multiply this figure by 12 and divide by 144 we shall have the number of square feet of paving, per conduit foot, on the 15 duct line, which is 4.7 feet. Our paving costs $1.44 per yard or 16 cents per square foot; then the paving per duct foot would cost $.0500, and per conduit foot $.7500.

HAULAGE OF DIRT:

Cost is based on bids submitted, of 50 cents per double team load of 35.1 cubic feet or $.0142 per cubic foot, and this figure is obtained on the basis of a double tip cart removing to the most convenient dump or other point ten loads per day of ten hours (the laborers filling the carts), at a cost of $5.00 per day for the team. On our 15-duct line we shall have surplus earth which must be removed, and at such times and in such quantities as will prevent criticism from the city officials and from the abutters, and therefore, as we know our trench is 32.25 inches wide and the total depth of the construction is 22.25 inches, then $\frac{32.25 \times 22.25 \times 12}{1728}$ equals the amount of earth or refuse we must remove for each conduit foot of the line constructed. This amount will be [illegible] cubic feet, and the cost per duct foot will be $.00[illegible] and per conduit foot $.0[illegible]

INSPECTION

[illegible] will insist on placing [illegible] found that the [illegible] separate [illegible] amount has been [illegible] Then [illegible]

INCIDENTALS:

Cost of incidentals is based on five per cent of the total cost, including every expense.

MANHOLES:

I believe we agreed that we would have 4 manholes in the line, and that the dimensions would be as follows: 5′×5′ area inside, 7′ deep, 8″ walls without shelves, drained to the nearest sewer, and having on each manhole a heavy frame and cover of the "sewer type." See Plate No. 1.

Then we shall need for material:

23.76 cubic feet concrete, cost in place $.202 per foot..........	$4.78
2,500 hard sewer bricks, cost $9.00 per M....................	22.50
$1\frac{3}{4}$ S. 6″ trap and connections cost	5.65
30 feet 6″ Akron sewer pipe, cost 30 cents per foot............	9.00
R.R. steel (60 lbs. to the yard), 8 pieces 6′4″ long (1013 lbs.), cost $.0125 per lb..................................	12.67
$1\frac{1}{8}$ yards mortar, cost per yard $3.98........................	4.47
1 manhole frame and cover, 962 lbs., cost $.015 lb.............	14.43
	$73.50

We shall need labor that will cost as follows:

Excavate and back fill part of same, including that for sewer connections, 785 cubic feet, cost $.0278 per foot..........	$21.82
Remove from street 304 cubic feet of dirt, cost 50 cents double load or $.0142 per foot................................	4.30
Pave 11.08 yards (including manhole and sewer connection), cost $1.44 per yard................................	15.95
1 mason 10 hours, cost 40 cents per hour..................	4.00
2 mason helpers 10 hours each = 20 hours, cost 15 cents per hour,	3.00
	$49.07
Total cost 1 manhole, complete..................	$122.57

We have now found the cost of the line per conduit foot and also the cost of one manhole, and we may now summarize and show in tabulated form what the cost will amount to for each item included in the line, both for material and labor, and for 1 duct foot, 1 conduit foot, and the total line, and we will make the table conform with the order in which we have taken up the separate items, so that the whole will be as plain as possible, and at the same time complete, and when the

table is complete the "central station man" can, it seems to me, easily figure the cost of a line other than our 15-duct line, the cost of which we have tried to find; but as a matter of course the prices of material change from time to time, and that must certainly be considered, and the increased or decreased cost of labor if necessary.

MATERIAL AND LABOR.	Cost per Duct Foot.	Cost per Conduit Foot. Total Expense.	Total Cost for each Item for the Total Line.
Material.			
Lumber at $15.00 per M. or .015 cents per square foot B. M.	.0105	.1575	233.10
Concrete at $4.85 per cubic yard or 18 cents per cubic foot	.0231	.3465	514.15
Mortar at $3.98 per cubic yard or 14 cents per cubic foot	.0026	.0390	58.90
Ducts laid down beside the trench at $.0502 per duct foot	.0502	.7530	1114.44
Labor.			
Excavate and backfill at 15 cents per hour or $.0278 per cubic foot	.0266	.3990	592.c6
Cut and place lumber at 20 cents per hour or $.0006 per square foot B. M.	.0004	.0060	9.32
Mix and place concrete at 15 cents per hour or $.0222 per cubic foot	.0029	.0435	63.48
Mix and place mortar at 25 cents per hour or $.0925 per cubic foot	.0016	.0240	37.00
Lay the ducts at 60 cents per hour or $.0040 per duct foot	.0040	.0600	88.00
Haul away the dirt at 50 cents per hour or $.0142 per cubic foot	.0047	.0705	104.72
Pave the trench at $1.44 per square yard or $.16 per square foot	.0500	.7500	1109.92
Cost of manholes per duct foot $= \frac{\text{Total Cost of Manholes}}{\text{Total Number of Duct Feet}} = \frac{490.28}{22,200}$	.0221	.3315	490.28
Inspection at 50 cents per hour or $.0033 per duct foot	.0033	.0495	73.26
Engineering expenses at $.0214 per duct foot	.0214	.3210	475.08
Incidental expense at 5 per cent of total	.0116	.1740	248.22
	$.2350	$3.5250	$5212.73

Now that we have the table, we had better see how we obtained the figures, that is, what method we employed, even though on preceding pages the figures themselves appear. The total line is 1,500 feet long and has 4 manholes, and the duct line will extend to the inside of the walls, and as the manholes are 5 feet square inside, it follows that 1,500 less $4 \times 5 = 1,480'$ or the total length of the duct line, and as the cross section contains 15 ducts, the total duct feet when the line is complete will be 22,200; and as we have already determined the cost per duct foot and per conduit foot, we have only to bear in mind that the total amount of duct feet in the line are the figures to multiply by, instead of any other, and is the proper method by which to arrive at the total cost of the duct line; and the total cost of the manholes should be divided by the total duct feet, in order to arrive at the proper cost of manholes per duct foot of line, and which, when added to the cost per duct foot of the duct line, gives a total cost per duct foot for the total line. A deviation from this method is liable to lead one astray, as small fractions will make a very considerable difference when a large number of duct feet are to be used. We now have a tabulated form and have shown how we arrive at these conclusions, and we know the cost of our duct line alone, per duct foot, its cost with the cost of manholes per duct foot added, the total cost per conduit or total trench foot which includes the manholes, also the total cost of each item for the total line, and in fact everything needed in the nature of an itemized estimate, and with the data on the preceding pages it is perfectly easy to tell how much material of each kind you need, and even how much money you need for your pay-rolls.

Of course the table is not correct for all types of duct, paving, or manholes, of a different type or size, than those given herein, but you now have the method at hand showing how the cost of the line, or a line, can be obtained, and also the sketches which will indicate the reasons for basing the figures as shown.

We have gotten at the estimated cost and now we will take up the methods of starting and carrying forward to completion the total line.

We can assume that the engineer and contractor are on the ground, and that the former has the requisite permits at hand to enable him to open on the first part of the line, and that you intend to make a start by opening about 300 feet or twenty per cent of the total length, and we will also assume that as you intend to finish 100 feet per day, or more, until the work is complete; you therefore can afford to have fifty men ready to go to work on the start, and your first move will be to

measure off from the curb or other mark, and with a piece of chalk or a line indicate the distance from the curb, and the next, the width of paving to be removed, and as soon as this is done have the men begin to bar out the paving, and as soon as you have a space showing dirt only, for a distance of 25 feet, get some of the men in the opening with the picks and let them work ahead. As more blocks are removed, and where the men have used the picks, get in some others with shovels and have the line followed in this manner until the blocks are out for the total 300 feet, and then put all of them on the picks and shovels, except what you need to open on the first manhole location, for this part of the excavation should be completed as soon as the trench. We can assume that in due season the trench and manhole excavations have been bottomed out, and in the meantime your material has arrived and side boards have been cut and cleated, one or two bridges installed over the trench, concrete has been mixed and is ready to go in; so the first side boards are set, and then the concrete can begin to go in for the bottom, and as soon as the first 25 feet of concrete is in and rammed, the duct laying can begin, as close to the manhole location as possible, and the duct layer must not forget to start his mandrels as soon as sufficient duct is laid to take them, and continue to draw them as the line lengthens and keep the ducts clear.

Now you have the trench fully under way and you find that the sewer trap is set and the concrete is going in for the base of the manhole, and that the mason's helpers have got the material at hand to start brick work; and now all of the work is started, and by the next day, or twenty-four hours later, you find that a system of working the men has been established, your duct is being laid, the side and top concrete goes in, the top planking is laid on, and you begin to back-fill the trench with the best of the material that came out; then you are ready to replace the paving and clean up as much as you can where the work is completed, and now you want to go ahead faster. By faster, I mean that having started with a few men, and having got them broken in so to speak, you must arrange to practically duplicate your force and complete at least 3,000 duct feet (200 conduit feet) or more of this size of line per day; for with the conditions favorable and work properly superintended, it should not require more than nine days at the outside to complete our 15-duct line, 1,500 feet long, with 4 manholes. Of course, if you are in a district in which you will encounter tide-water, or if you have difficult obstructions to overcome, such as water or gas mains, or any other services, and if you have to build water-proof manholes, or spend a great deal of time in getting such services as spoken of re-

moved, then the time required will be greater, as will the expense, and under such conditions as above there is a good opportunity for your general foreman to exercise his skill in finding work for his men, of a profitable nature, on other parts of the line, and to show his judgment in laying them off, if necessary, until such arrangements are completed as will admit of procedure on the line at a rate of speed that will warrant the figures that will show on the coming pay-roll.

I think, perhaps, that the "central station man" can now see fairly plain what is required to build his line, from the first step necessary down to the time when he is well under way with the installation of the same, and we can assume also that he can finish it without difficulty; but we have talked of a plain and simple line, for that is the easiest to illustrate, and shows what you must do in order to complete the installation of any line of a like nature.

I realize, however, by experience, that at times we must build lines under bridges, perhaps over or through them, and under, over or through all sorts of obstructions, and constructions, some of which may be our own, but if they are visible on plans before we open ground, and proper thought is given such matter, they are not difficult as a rule, and if we meet them after opening ground we must think the matter out as soon as possible, always keeping in mind that if it is required to obtain permission to cross in any way another corporation's property, a start should be made at once in that direction, and not find, when your plans are nearing completion for any special work, that such permission is impossible to obtain and that the time of several men has been wasted. In fact, the principal part of the proper method of handling underground work lies in the ability of those in charge of it to look ahead and be ready to let the working force, which they know are coming behind them, into the location without delay; and unless this condition obtains the work will be expensive.

CABLES:

When the "central station man" has completed his conduit, the next item he needs will be cables, and as we speak of them you will recall that in preceding pages I said that "it was the imperative duty for the assistant engineer to make notes on the conduit line, with such accuracy and in such volume as to absolutely correct the original plans," and if this has been done you can easily find out how much cable you need, from the measurements he has furnished, as the plan for each section of the line should plainly state the length of cable needed in that section and have included in the figure twelve inches square on

each end of the length so that the cable jointer will be able in his work to cut back any distance within that limit and cut the cable at a point where there is no dampness (which may or may not have accrued on the extreme ends of the length) and where the form of the sheath, insulation and core of the cable is perfect.

If you have a low-tension distribution system, you will use perhaps cables from 2,000,000 cir. mils concentric and 1,000,000 cir. mils single conductor, down to 500,000 cir. mils single conductor for feeders, and from 500,000 cir. mils down to 200,000 cir. mils for mains. If A. C. is in use probably you will use a great deal of cable which has more than one conductor under the same sheath and, of course, the saving of duct room is added to the other advantages when you can use such a cable, whether it be in the A. C. or D. C. system. The insulation for the feeders and trunk lines will probably be paper, as it is best adapted for an overload of amperes, and its insulation to the ground shows a very high resistance if it is well jointed. Do not, however, insist on having a paper-insulated cable test too high. I have learned from more than one reputable manufacturer of cable that they could give you this type of insulation on a cable to test 1,000 megohms to the mile, when in their judgment 500 megohms to the mile was much better, as the resistance of the insulation was dependent, if the same cable was considered in each case, on the amount of drying out by heat that the ingredients used in the insulation received, and that the drying out process reduced the flexibility of the insulation and made it more liable to crack when being bent into place; and we know by experience that a cable with the paper insulation cracked or broken will be used in service but a short time, on either a high or low tension line. The better way is to determine what cables you need in sorts and sizes, and specify the quantity of each, and submit the list to several reputable concerns, with your request for a price and guarantee from them, on each type of cable, to cover a term of years, say five, being careful to state in your specification what the cable is to be used for, whether A. C. or D. C. work, the voltage to be used on the line and the ampere carrying capacity required, and then let the manufacturer furnish such cables, with an insulation resistance (to be specified by him) to the ground, that he thinks will stand with the specified voltage, and still maintain his guarantee given you in the contract.

INSTALLATION OF CABLES:

I would much rather see the concern which furnishes cables for new work install them, and for the reason, first, there is a guarantee on

the goods, and if, when the dealer installs them, after the total line or lines are drawn and jointed, they do not test out properly, the burden of making them right falls on the vendor without question.

I would first tell him in specification that he must rod the ducts, at the same time informing him that the company had drawn mandrels through every duct as it was laid, and that they were clear to the best of your knowledge; but notwithstanding that fact, if he did not rod them and then encountered difficulty, such as having cable sheaths cut in process of drawing, that he would be responsible for any expense incurred thereby. When the ducts were known to be clear, and the drawing-in done to an extent that jointing could begin, it would not be necessary to say to the cable contractor, you must not joint cable in wet weather, or you must not delay jointing in dry weather, for the conditions of the contract, with reference to the guarantee, would not consistently admit of progress in one case nor delay in the other, when by the contract we know that he is to rod the ducts, draw in and joint the cables at a stated price per foot, and the sooner he can get the work done, and well done, the better off financially his company will be.

If the manholes are shelved to receive the cables, as shown in Plate No. 3, the cable contractor should be required to form all of the lines into their respective shelves in a neat and workmanlike manner, taking special care that joints are so located in different lines that when shelved they will not lie directly one over the other, and also he should be careful that joints are so placed, if possible, as to avoid being trod on by workmen — careless workmen is the proper phrase — when climbing about a manhole for any purpose. If the manhole is plain (without shelves), then the cables should be racked in a neat manner as shown in Plate No. 4, Figure 4; and if a transformer is in a manhole (see Plate No. 5), or a catch box (see Plate No. 4, Figure No. 2), great care should be taken with the bending of the cables to meet these terminals, so that the radii of the bends will not be too great, and yet be as great as possible, and not interfere with future installations of cables, transformers or boxes.

ELECTROLYSIS:

If your installation is in the ground near a street railway system, where the rails are bonded, and the return conductor is not fairly proportioned on account of a probable cost of copper to make it of proper proportions, and more especially if the ground is wet and what is usually termed "made land," then the lead sheaths on your cables will be liable

to carry stray currents and, if they do, damage will occur sooner or later, which will result in the drawing out of a faulty cable and the replacing of same with a new one of like size and length. There does not seem to be anything left to do in such matters as this except to protect yourself at a cost which, in the end, will be far less than the cost of replacing lengths of paper cable whose sheaths have been eaten through by the electrolytic action, for such action will take place when the current leaves the sheath to the ground, and if you know this in time, as perhaps by actual experience you do, you should — on the new installation — decide to circulate through your duct system in the railway district a bare copper wire of, perhaps, 200,000 circular mils cross section, and have one end of it attached to the return conductor of the railway system, at a point as near the railway power house as it is practical to get it, and with as good electrical connection as is possible to have; and from each sheath in each manhole connect a small bare copper wire, say No. 20, by making several wraps around the sheath, and attach the other end to the copper conductor first mentioned, being careful to make the best electrical connection possible between the sheath and the large copper. The result will be that the sheaths will discharge their currents to the large copper, which will in turn discharge its current into the return conductor of the railway system and electrolytic action on the lead sheaths will be avoided.

In case you intend to use cable mains on your underground system, the handholes for distribution from same can occur in any part of the duct line where needed and space is available. The handholes are built over the line, and so that the top row of ducts will enter either side of it (see Plate No. 4, Figure No. 3), and inside of the handhole there is placed on steel supports, made of light steel tee iron, what is termed a cross, or service box, which is made in either a two or a three wire type or form as required, and from the catch box in the manhole (see Plate No. 4, Figure No. 1), the main cables leave and are extended through the top layer of ducts to the handhole. They are then picked up, and extended through the terminals of the service box, which has a water-tight stuffing box for each cable in the main, and cut at the proper length to take a lug, which is, when soldered on the cable, bent down and connected to the bar terminals in the box. This is a very convenient way of installing mains and services; there are methods less expensive but not better, for here you have a water and gas tight box, a first-class opportunity to extend services to either side of the street, and, above all, the best of methods by which in time of line trouble to test from house to house, and from manhole to manhole, without re-

jointing any cable or keeping any customers out of service but a very short time. The same thing can be done from the manhole itself, but if the distances between manholes are long and your services are heavy, and require separate service wires or cables for each building, your manholes will become crowded and the chances of encountering obstructions in installing services are greater. In either case the service wires would lead from manhole or handhole, through a 3" iron pipe to the customer's premises, and terminate on a service switch. Plate No. 5 shows pipes of this description, one going to a street lamp, and showing a connection from pole line to manhole.

CARE OF CABLES:

Cables once installed should be looked after carefully, and it should not be assumed that a manhole does not need inspection, or cleaning. On the other hand they should be inspected regularly, and kept clean. The sewer connection should be known to be open to the sewer, and not be liable to flood, and the cables should be tagged in every manhole, and in case concentric, or other cables of more than one conductor, burning out, a provision should be made to protect other cables near by from having their respective sheaths burned by wrapping them with asbestos ribbon, and thereby avoid trouble on several lines at one time. Care should be taken, also, to caution employees about treading on cables and cable joints at all times, and especially in manholes, where usually the conditions are of the best to destroy cable, if the slightest opening occurs in the sheath. If the cover of a manhole is a perforated one, and such I would prefer, unless the manhole contains transformers, it should be looked after as regularly as the manhole is inspected and let the duct system get all the ventilation it can from that source; and if the manhole is built for, and is required to be water-tight, then the cover and joint should be regularly inspected and kept tight, and save the apparatus therein from receiving water, after an expensive manhole has been built to prevent that identical occurrence.

MANHOLE BOXES:

Like boxes for mains, the feeders in the system may terminate in some suitable receptable, placed in a convenient position in the manhole, and being capable of being made water-tight, (these, of course, are applicable to D. C. lines only,) and may have fuses and bus-bars either straight or circular.

There are types which fit to the wall of the manhole which are of large capacity, convenient to operate and water-tight. There are other

types which may be hung from the roof of the manhole, and operated from the surface of the street. In winter weather, the box in the manhole is in a better place to operate than the one which opens at the surface, and, all matters considered, I had rather have the box in the former location; and, as a matter of fact, I am of the opinion that it is the safest location, if well installed and cared for.

I do not lose sight of the fact, however, that there are many instances where, in manholes, there is not room for a box, and in such cases one must use that which is available.

FROM OVERHEAD TO UNDERGROUND:

Plate No. 5 shows what the "central station man" can do when his conduit line is complete, his boxes installed, or transformers if may be, and his cables drawn in and connected to their terminals; whether it is for one block along the line, or more, both in the case of his series arc lamps in the street, and his overhead low-tension mains or his primary and secondary lines. I believe the items are shown fairly complete so far as the construction needed applies, and with the lines open at the station end, and fuses off in the boxes in the manhole, it would not be difficult to make the transfer, and when the section over head, as shown, has been connected to the new section of underground, the work of removing wires and poles could begin and be carried on from time to time as new sections of underground were installed and conditions would permit. I have in this type of underground system included necessary construction for transferring present overhead lines to underground, involving only such capacities as were contained in the overhead lines, the only other stipulation being that, in building your conduit line, don't fail to determine what you need for future development as far forth as possible, and if the city or town is a large one, or a small but growing one, don't guess on the minimum side for the size of the conduit, and have to open the same street or streets twice, pay a contractor to get his outfit there and away twice, and pay for the paving more than once. If you don't fail on these points, the abuttors and your customers will congratulate you on your foresight, especially if they are stockholders, and you will congratulate yourself on the second line you build (and think it too large) when in an incredibly short space of time you find your ducts are filled; and besides there are concerns who have to hire duct space in these days, and from prices paid, some of which I have in mind, I can easily see where the investment would be a profitable one for the "central station man" who had duct space to rent. Therefore, consider the matter well, before you

decide that you cannot afford to build an 18-duct line, instead of a 15, while you have the ground open. Lay out the cross section of an 18-duct line and figure it; your manholes will not cost you any more, your stock and labor will be in a very large degree less than it would cost to open the same ground again, and if your present 15-duct line is to have its capacity taken, or nearly so, and a new enterprise of some sort comes into existence, which you had not the remotest idea would ever exist, and the concern expresses a wish to become your customer in the near future or not at all, then, as you have duct space, you are ready for a heavy customer, except perhaps for cable, and that can be obtained from stock if it is not in too large size, and you are then in a position to take on the new customer while perhaps the competing company or companies in your town, in your line, who have been more cautious in the matter of conduit installation, will be unable to accommodate prospective business.

I have covered the conduit system in a manner which I hope will enable the "central station man" to see his way clear to put his conductors into that type of system, and without difficulty. There is, however, another type of underground system which is the well-known Edison Tube System, and under certain conditions, such as those where lines which are not too long are required, and where the load for the line will be fairly heavy, in amperes, and the volts needed do not as a rule exceed 300, it is a good system to use. It will compare favorably as to cost with the conduit system for short distances; but while the cost of installation under these conditions may be favorable, the cost of operation favors the conduit system to a large degree.

If the "central station man" should wish to use the Edison Tube Underground System, it would be necessary for him to follow in general the same method of procedure with reference to survey, right of way, and placing of contract, also with reference to the bonds for faithful performance of work, accidents, and the maintenance of street surfaces for a period of time conforming with the requirements of the city in which the system is to be installed; and when these conditions have been met, and properly taken care of, the work may proceed.

If the city is one of medium size, and the business portion especially is not scattered, we can assume that the location of the feeder terminals has been fixed at such points as have in the survey indicated the heaviest loads. If the station is to be near the waterfront, and the distance is not made greater by reason of such location, we can use one street only for some distance, to carry along, say, ten feeders; or, in other words, ten Edison tubes, having in each three coppers. Two

of these are used for the positive and negative, each having a diameter of one inch, and the third wire is used for the neutral and has a diameter of .59 of one inch, and the three coppers taken together with the pressure wires represent one No. 1,000 feeder of an Edison three-wire system.

We want to lay them all in one street if we can, for the reasons following:

It will be cheaper; as the trench need not ordinarily be lower than 30 inches from the surface, locations can be secured much easier than with the conduit system; the material which is heavy will be handled cheaper; the labor can be superintended for less cost, and the re-surfacing can be done with greater facility. Assuming we are ready to start the work, with the necessary foreman and sub-foreman at hand, we start in and get the blocks out, then get the men in with the picks and shovels, and as soon as the trench is bottomed out for 30 feet in length we can begin to drop the tube in place, and get the jointers at work on the connections, and as the excavation progresses we can get in more tubes and connect them. In the meantime the compound kettles have been heated, the clamps and the coupling boxes have been placed under and over the connections between each end of the connected tubes, and have been bolted together and are ready to have the hot insulating compound poured in them. The boxes may not be filled too fast, nor too near full at first, for it will be better, if they are filled two-thirds full, to let any steam which may generate from the contact between hot compound and cold iron have an opportunity to dry out, and later on fill the boxes completely, and then screw the plugs in the pouring holes. Perhaps at this time we have reached a point on the same street on which we started, where a feeder ends, and if so we need a 6-way or a 10-way 1,000-ampere catch-box or junction-box; that is an underground device of 1,000 amperes capacity and having 6 or 10 stubs projecting from its base, two of which are for feeder connections, the others being for the purpose of connecting the mains, of which we shall speak later. (See Plate No. 6, Figure 1.) Therefore we excavate for our catch-box, set it and cut a piece of tube of the proper length for the space intervening between the end of the last length of tube, laid for this particular feeder, and connect it to the line and also to one of the feeder stubs of the catch-box, and we may then call that particular feeder connected except at the station end. Such portions of the lines as have been connected and completed may have a length of plank laid on each and the trench may be back-filled. We may also assume that, from the point where we set the first catch-

box, which would naturally be at the junction of two or more streets, the balance of our group of feeders would begin to lead in three different directions at least, in order to have them arrive at the points indicated on the plans as feeder terminals; but as the method of getting them there and making the terminal has already been described on one feeder, we will consider that description sufficient for the balance of the group, or the other nine feeders. We have not, however, said anything yet about providing for such an emergency as having one of these feeders out of service, or how we would keep the pressure in the district fed by that tube at standard.

There is a device that can be and is used to cover such cases, called a feeder-box, which differs from what I have described as a catch-box in that it is used for manipulating feeders, in case of accident to one or more of the group.

For instance, if we install a four, six or eight stub feeder-box in a group of feeders, and enter the group from one side of the box, and connect them to the cables of the box on that side, the current will then be carried in and through the box to the other side, and out to the other portions of the lines; and if one feeder of the group becomes faulty, we can by means of a set of cable jumpers, so called, connect the good portion of the faulty feeder to some one of the group of remaining feeders that are perfect, and, if the faulty feeder is burned out on the station side of the box, you can still deliver some current from the good lines through the jumper cables to the terminal of the faulty feeder. If the feeder is burned out on the feeder terminal side of the box, you can still use the cable jumpers, and send all the current you can to the several terminals of the good feeders, and thereby increase the circulation of current from their respective terminals and keep the pressure as near standard as possible at the terminal of the dead feeder. In fact a feeder-box is an extremely useful piece of apparatus, and if I intended to install a complete tube system, I should by all means install a number of these boxes at points where three or more feeders were located in any one street. Plate No. 6, Fig. 2, will show the feeder box and the use of the jumper cables.

Not only for uses already described are the feeder-boxes available, but they are valuable indeed when grounds or crosses occur on the feeder system, for it is then possible to cut the feeders into sections and test in either direction for the difficulty.

If the "central station man" has had his system installed for some years, and feels the need of a small sub-station from which he can extend a few feeders in the direction of a growing business district, and

his system is, as first installed, a purely low-tension system, then he will probably need one or two tie or trunk lines. These are lines which leave the "bus" in the power station and extend, exclusive of any connection with the underground system of mains, to the "bus" in the sub-station; and, if so, these lines will necessarily be operated at a higher voltage than his feeder lines, for it will also be necessary to obtain, in order to use the same voltage lamps throughout, a "bus" voltage at the sub-station which is practically the same as the feeder "bus" voltage at the power station, although that depends entirely upon the amount of load and the length of the feeder from the sub-station. When such lines are installed, if they are tube lines, as we now assume they will be, the type of feeder-box before spoken of should be installed not further apart than 1,000 feet, for the cost of the installation of the boxes, in case they were not used and repairs were needed, would in a short time be overshadowed by the cost of making openings in the street from which to make tests, not to speak of the time saved in the interruption of service and the vexations attendant thereto.

We can utilize still further these tie or trunk lines, for if we wish, as a matter of insurance, we can connect these lines to the catch-boxes through the medium of an underground switch-box, a device which can be operated electrically from the switchboard in the power house; and when you have a feeder which is heavily loaded develop an open circuit, you can by operating the switch-box throw the current from the tie line into the system of mains — having first opened the switches in the sub-station on that particular line — and put the switches in the power station from a "bus" of high voltage required for a tie line to a "bus" of lower voltage as required for the district which you intend to feed.

In the matter of mains, or the line from which you will tap service lines for your customers, do not make the serious mistake of having the first installation of these lines go underground with the copper just large enough for present use, or with a very small margin for future use. When you install them you may say you have enough copper in the ground to cover the business for a number of years, but don't forget at that time that if your guess is erratic you are bound to have an overload which will mean a higher amount of energy lost, excessive cost for repairs, interruption of service, and arguments from customers who may, perhaps justly, complain of unsatisfactory service.

Lay the mains on both sides of the streets in the business section if you can possibly afford it. It costs you a certain amount of money for plans, etc., to prepare to lay any line, and the men, tools and stock

must get to the spot before you can begin, and when you have them there, don't make the mistake of not having the stock and keeping them there long enough to lay an amount of line sufficient for use as far into the future as careful judgment will dictate, for the amount of money you can spend in making a second preparation will pay the interest on quite an amount of investment in copper for future use, not to speak of having yourself in position to take on a large customer on short notice, and thereby perhaps save the business to yourself instead of seeing it go elsewhere. All of the coppers in Edison main tube are usually of the same size, and nothing smaller than 200,000 circular mils area for each copper should be considered in any installation, that is, in a growing city, and you may decide that 350,000 or 500,000 would be more to your advantage in the end, after you consider interest charges, maintenance, and the value of being able to take on business in fairly large items. The reliability of this type of main to carry its rated load is not to be questioned, and the repairs are not as a rule excessive on a well installed system. Of course they are not as easily gotten at to repair as cable mains, but, on the other hand, they cost a good deal less to install than a drawing-in system with handholes at convenient locations.

The installing of mains should contemplate the setting of a junction or catch-box at every street corner, or at least on one corner of every junction of streets, so that when your total system is installed and line difficulties occur you will be enabled to open catch-boxes, take off fuses, make dead any one section of your system of mains that will be most convenient for your purpose, find your trouble easily, and inconvenience only such customers as are on that particular section.

Just a word about the boxes of all kinds which you have in the system. It will pay you, after you have them well installed, to inspect them regularly and know that the fuses or catches are intact on every copper which has its lead from the box, and keep them clean. Do not assume, when the box is once in the ground and sealed, that so long as you have no line trouble they are O. K. You may have a customer who complains of poor light and notices that his neighbor across the street has a much better one, and in such a case, if the two customers are feeding off different mains from the same box, you may find on opening the box that the cause of poor light to the complaining customer is the fact that the current is feeding to him from one source only, on account of a blown fuse. Take care of the system; it pays in the end, and has been so proven by experience. Service lines we must also have, and 100,000 circular mils is small enough to install underground,

for you cannot afford to do the work, or at least incur the expense of service installation, for a less capacity than that of the service above named, which is 100 amperes for each conductor. A 3-conductor cable insulated with rubber, jute and asphaltum, and with a steel ribbon armor outside, is good for the purpose, for it is small, flexible, easy to work, handy to connect, reasonable in price, and durable.

If service lines are being installed at the same time mains are being laid, of course much expense is avoided; but it is necessarily true that many services must be installed after the main line is complete, and in the latter case the ground can be opened over a coupling-box in the main, and then a very small trench extended from that point to the customer's premises where entry is made, a service switch installed, with the necessary fuses and the cable connected thereto. Before back-filling the trench kyanized plank should be used to cover the cable, to prevent the picks in hands of other workmen from injuring the cable in the future. The line need not be made dead for the purpose of installing this type of service if you have what we term a good "live wire man" for a jointer ; but in case you need a larger service which is, for instance, the same size as the main itself, the line would be made dead long enough to put in the proper connection, with a tee box, to replace the straight coupling box before used at that point. In case of customers who have heavy and important load demands on the system, the main itself is sometimes led into the building and out again in the form of a loop, so that when this service is connected complete to the loop service switchboard, current will be taken from the main in either or both directions from two junction-boxes, and if the main on one side of the loop becomes faulty the other side is still available. Do not make the mistake of installing services on a too cheap basis. Make your terminal switch substantial, and have the cable leads which are connected to its terminals put up in a thoroughly substantial and workmanlike manner, well insulated, and in fact in such shape that it will reflect credit on your method of doing business with customers.

And, now, as to the difference in cost of the two systems, I can say that the tube-feeder line is cheapest but not best. I have in mind one trunk line laid in conduit in 1890, which was 4,255 feet long and which was drawn into a new conduit. General electric, rubber insulated, lead-covered cable was used as follows: two 1,000,000 circular mil cables for positive and negative, and one 3-conductor pressure cable. We did not draw in a 350,000 circular mil cable for the neutral, but if we had it would have cost 48 cents per foot, drawn in and jointed, and that would have made the total cost of one foot of the line, including

ducts, cable, and every item to make the feeder ready to go into service, $4.044. This with the price of copper at 19 cents. If we had used for the same line No. 1,000 Edison tube, with a junction-box installed at its terminal, the cost per foot of line would have been $3.27 or about nineteen per cent less than the line in the conduit system; but, on the other hand, even though we had cut the tube line in sections by reason of installing the feeder-boxes I have previously spoken of for testing purposes, no doubt we should have paid to date on the tube line a very large percentage for repairs and renewals, more than we have for the cable line, and the excess of its cost over tubes. On mains it is the same; the installation cost is greater, but with cable mains properly installed, and not allowed to be overloaded, repairs can be made quickly and without opening ground, when with the tube mains you must open the street, be it winter or summer, and at much expense. On services as on mains it is equally true, for with handholes and cross boxes as before referred to, repairs may be made quickly and safely, at small expense, and with no detriment to other customers on the line.

To sum the matter up, the advantage appears to exist in the conduit system undoubtedly.

One word about the number of cables in a single duct. Don't crowd them too much. You may at times have to do such things as that, when, after your conduit is complete, in due course of time you find that you are short of duct room; but if so, on the next occasion of duct installation add a few more than you may need, at least twenty-five per cent, for in your past experience you may have found that it would have been cheaper to have had some spare ducts, with the investment for the same lying idle for awhile, rather than have paid for the repair or renewal of cables upon which no expense would have been incurred provided you had not been obliged to crowd ducts with more cable than they should contain. In this connection, also, do not let the value of a conduit location pass in a disinterested way. Bear in mind that in these days everyone wants wires to go underground, and a location for a conduit should be considered a valuable acquisition, and the most careful use should be made of it, to utilize to your utmost ability something which you have for your own use at present, but at the same time something which all "central station men" are looking for all of the time, and which, if the business is growing, they will utilize probably to your detriment, if you do not exercise good judgment and fill the location for your present and future uses.

About ducts, of which there are many types and many makes, use

a good clay duct, from a responsible concern. Make it single or multiple according to the conditions which surround the installation of your system. Look up the different types in a thorough manner. Ask people who have used ducts and get their experience, and find out that which seems after investigation to be the best.

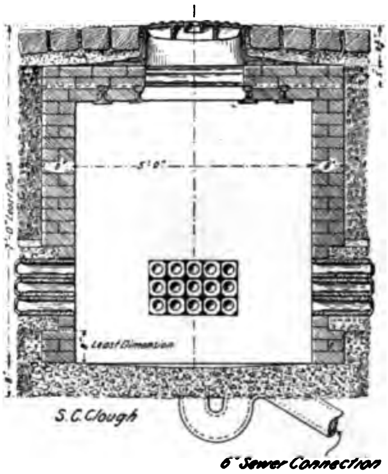
On the question of manholes, don't scrimp on them. A badly-shaped manhole, too small, with not the proper space to install cables, not to mention the fact that your men have got to work in them, to make repairs at any time in twenty-four hours perhaps, may be the means of adding more expense than several times the amount it would have cost you for stock and labor to have built them right.

When you have got your duct and cable systems properly installed, and you look at the cost of maintenance each month as compared with your previous cost of maintenance of overhead lines or tube system, you will feel a sense of satisfaction that you did not before experience, and in case of trouble in the streets, by reason of fire and the many other difficulties which tend to make overhead lines the bane of a "central station man's" life, you may rest content, for then the system will be to a greater degree under your control only, than ever before.

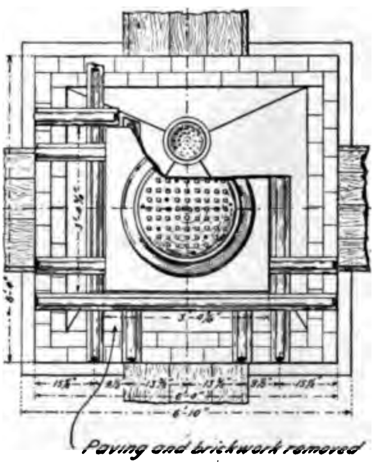
Concluding, I will say that it has been my intention to include in this paper such information as would be in compliance with the request of the Secretary, and all of the detail has been taken into consideration that seems necessary to enable anyone in the central station business to proceed with the installation of a new and complete underground system, or to change from an overhead to an underground system, without serious difficulty.

W. P. HANCOCK.

SQUARE MANHOLE
5'-0" X 5'-0" X 7'-0"
8" WALLS



SECTION



PLAN

PLATE 1

SECTION OF A 15 DUCT CONDUIT

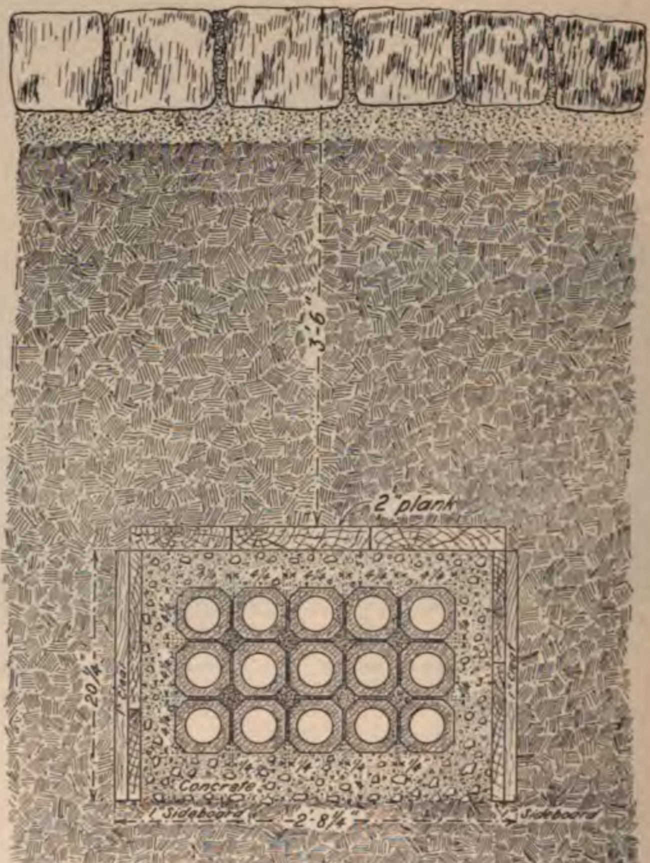
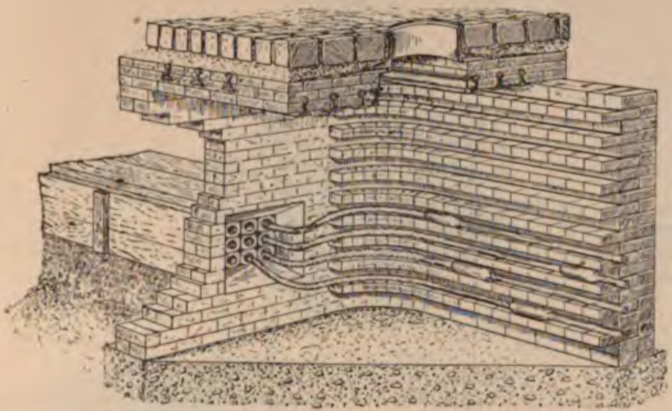
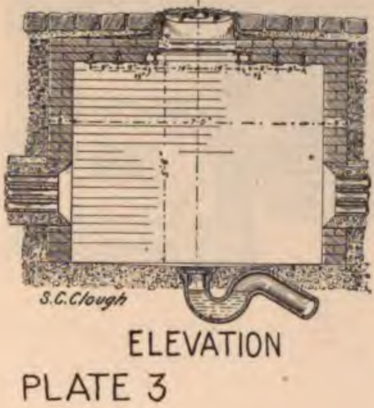


PLATE 2

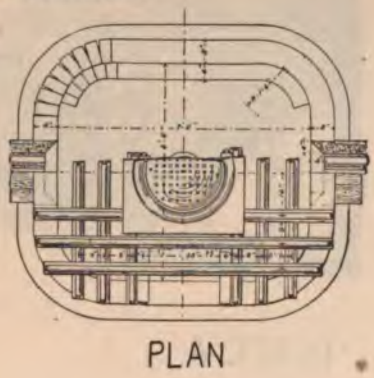
SHELVED MANHOLE



CORNER VIEW
Showing brick shelves and arrangement of cables and sleeved joints.



ELEVATION



PLAN

PLATE 3

Fig. 1

Fig. 2 Fig. 3 Fig. 4

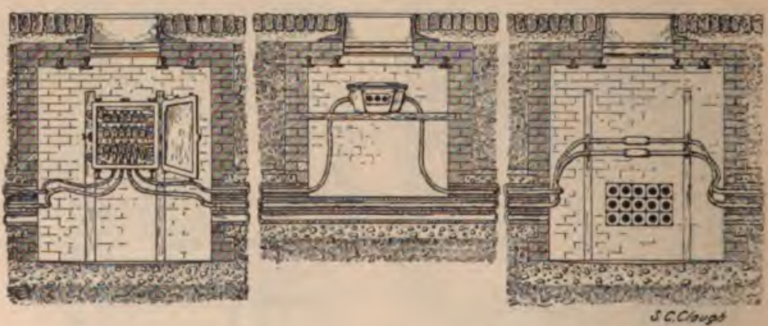


PLATE 4

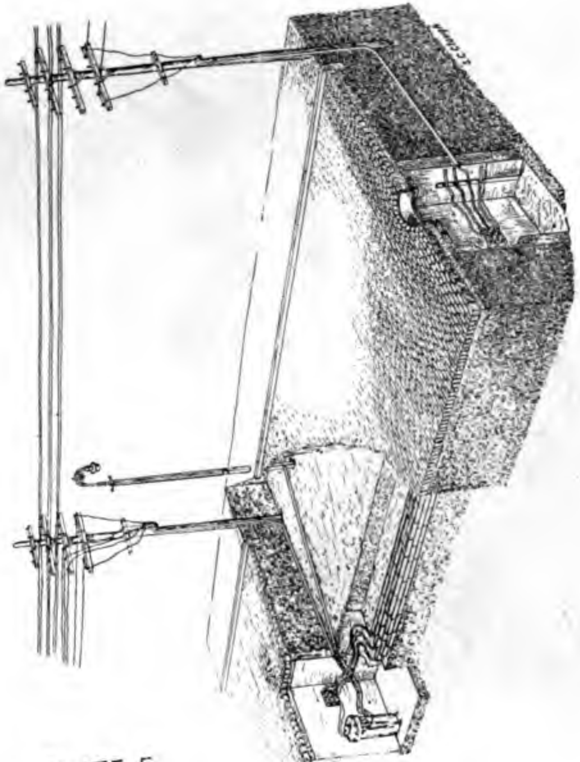


PLATE 5

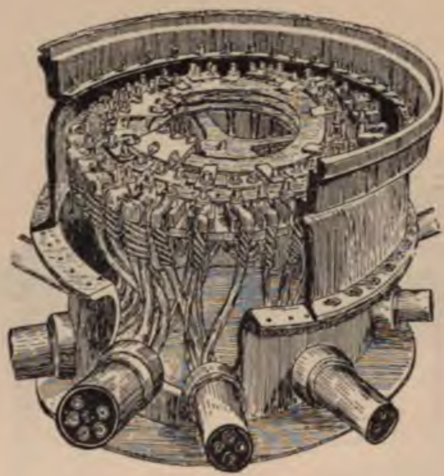


Fig. 1

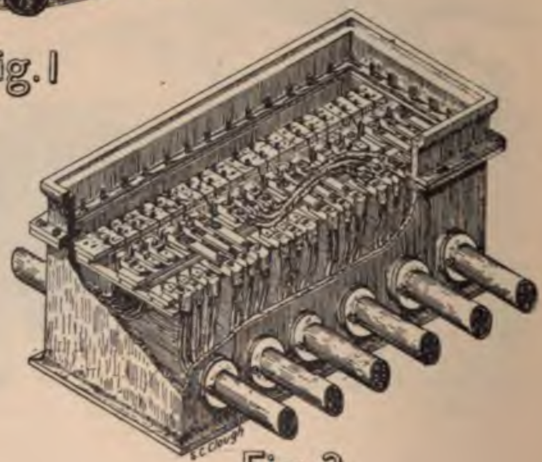


Fig. 2

PLATE 6

APPENDIX B

Decorative and Sign Lighting

Illustrated

Twenty-Seventh Annual Convention

of the

National Electric Light Association

held at

Boston, Massachusetts

May 24, 25, 26, 27, 1904

The New Lyceum Theatre—New York

A Report

by

Arthur Williams

Printed—not published

Press of
The New York Edison Company

1904

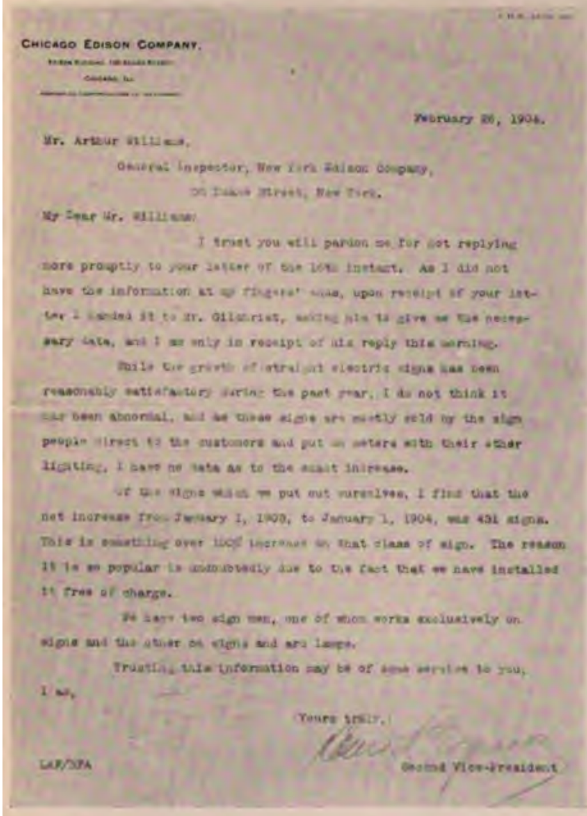
A Study in Lighting

Decorative and Sign Lighting

A Report

IN preparing this report effort has been made to select, from the material at hand, that which might best answer the purposes of the Association. It would seem a waste of time, and an instance of misdirected effort to attempt an explanation of methods or details of construction and, consequently, the report is made up almost entirely of illustrations, in which it is expected that suggestions of a various nature will be found. Where there is indecision concerning what is best for a given purpose, the mind will obtain the desired idea, the most appropriate of many, in glancing across a number of illustrations more or less pertaining to the purposes in view. Experience has shown that nothing more than this is necessary to those directing electrical work, to whom the faintest suggestion almost invariably leads to the most satisfactory results.

Merely suggestive



CHICAGO EDISON COMPANY,

February 26, 1904.

Mr. Arthur Williams,

General Inspector, New York Edison Company,

55 Duane Street, New York.

My Dear Mr. Williams:

I trust you will pardon me for not replying more promptly to your letter of the 10th instant. As I did not have the information at my fingers' ends, upon receipt of your letter I handed it to Mr. Gilchrist, asking him to give me the necessary data, and I am only in receipt of his reply this morning.

While the growth of straight electric signs has been reasonably satisfactory during the past year, I do not think it has been abnormal, and as these signs are mostly sold by the sign people direct to the customers and put on meters with their other lighting, I have no data as to the exact increase.

Of the signs which we put out ourselves, I find that the net increase from January 1, 1903, to January 1, 1904, was 431 signs. This is something over 100% increase on that class of sign. The reason it is so popular is undoubtedly due to the fact that we have installed it free of charge.

We have two sign men, one of whom works exclusively on signs and the other on signs and arc lamps.

Trusting this information may be of some service to you,

I am,

Yours truly,

Second Vice-President

LAF/DFA

The illustration of the ballroom of the Waldorf-Astoria indicates the ease with which it was possible to festoon the balconies, and thus with the aid of other decorations to produce an effect, said by those in charge of the hotel, not to have been equaled before. When this decoration was under consid-

eration, there was some question as to its effectiveness; now, that experience, or a glance at the illustration will remove any further doubt. Cause and effect are shown, and there is left only the intermediate question, whether the circumstances justify that the means shall be provided. And what is true of the ballroom of the Waldorf-Astoria, applies with equal weight to any other decoration or effect of that character.

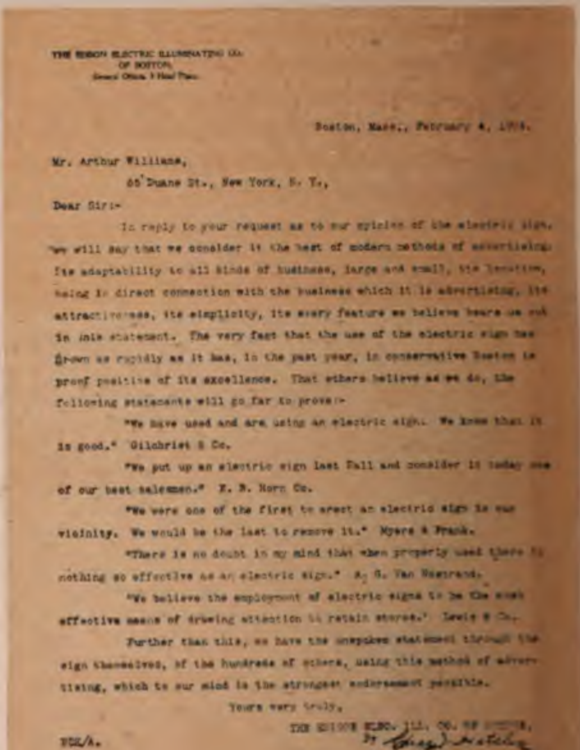
The Institute Dinner

Again, the decoration of the rotunda of a large department store, appearing on another page, shows the effect for another purpose in another kind of treatment, and again there is left only the question whether the necessary means are to be provided. It is regretted that this photograph does not show the hundreds or thousands of incandescent lamps shining through the mass of green similax, which, introduced as an opening day advertising medium, was a striking success.

In a Department store

The photograph of the Williamsburg Bridge, taken on the opening night, shows the towers and cables outlined with incandescent lamps, in combination with a great display of fireworks — above the bridge, consisting of aerial fire effects, and below, an attempt to reproduce in fire the falling waters of Niagara. The tendency to call for the assistance of the electrical people in matters of this kind is increasing, and they should be ready to respond with results striking and artistic. Any of these reproductions tells far more through

Municipal display



THE EDISON ELECTRIC ILLUMINATING CO.
OF BOSTON.

Boston, Mass., February 4, 190[illegible].

Mr. Arthur Williams,
65 Duane St., New York, N. Y.,

Dear Sir:-

In reply to your request as to our opinion of the electric sign, we will say that we consider it the best of modern methods of advertising. Its adaptability to all kinds of business, large and small, its location, being in direct connection with the business which it is advertising, its attractiveness, its simplicity, its every feature we believe bears us out in this statement. The very fact that the use of the electric sign has grown as rapidly as it has, in the past year, in conservative Boston is proof positive of its excellence. That others believe as we do, the following statements will go far to prove:-

"We have used and are using an electric sign. We know that it is good." Gilchrist & Co.

"We put up an electric sign last Fall and consider it today one of our best salesmen." E. B. Horn Co.

"We were one of the first to erect an electric sign in our vicinity. We would be the last to remove it." Myers & Frank.

"There is no doubt in my mind that when properly used there is nothing so effective as an electric sign." A. G. Van Nostrand.

"We believe the employment of electric signs to be the most effective means of drawing attention to retail stores." Lewis & Co.

Further than this, we have the unspoken statement through the sign themselves, of the hundreds of others, using this method of advertising, which to our mind is the strongest endorsement possible.

Yours very truly,
THE EDISON ELEC. ILL. CO. OF BOSTON,
By [illegible]

[illegible]/A.

the glance of an eye than could be told—and understood—through the medium of reams of word pictures.

The electric light entered into the political campaign of New York City during the past year to a much greater extent than formerly. On one of these pages is shown its first application to an aerial banner—that of the John F. Ahearn Association. The border of lamps attracted attention from many blocks away, and the illumination was sufficient to make the banner as effective in the night as during the day. Mr. Ahearn carried his district by an enormous majority, and this method of advertising, might have been largely responsible for the result. Some other ideas in political advertising are shown on a neighboring page. All communities in which politics play a part present unlimited possibilities for service of this nature.

Electric light in a municipal campaign

Some of the supplying companies, are themselves using Electric Signs, so profitable to private users. On one of these pages appears such a sign recently erected by the Boston Edison Company; on another is an example by the New York Edison Company. The buildings so advertised are large, and occupy most prominent positions. No other means of equal effectiveness have been devised for telling the story which the companies wish the public to know—the superiority of the central station service over the private plant. Impressions are created of

Sign advertising by the companies

Pabst's and The Majestic—Eighth Avenue and Central Park, New York City

the striking effectiveness of the electric sign—if here, for this purpose, elsewhere for any purpose; the central station service is advertised in comparison with and against the private plant; the electric elevator against the hydraulic; the electric motor in contrast with other methods of obtaining power. Further, the sign advertises the building to which it is attached, bathing the neighborhood with light, creating a scene brilliant and attractive.

Sign designs and positions

Many of the illustrations show possible varieties, artistic and otherwise, in sign design and the different positions in which signs may be placed. Some advertisers prefer vertical positions, others horizontal; some select the roof, others the lower portion of the building. To some a plain letter will appeal; to others one of fancy design. One cannot pass along Broadway without noticing the illuminated front of the "Hofbrauhaus," outlined in light below with initials above in turn surmounted by a crown of electric lights. The night photograph of the Broadway Theatre shows three applications of the electric light and gives an idea of the extent to which this method of advertising is used in the neighborhood. When the photograph was taken a storm was prevailing so severe that the street was deserted, yet the light remained, telling its story to an absent audience. The Thorley sign on another page, shows the effectiveness of fac-simile treatment, and the marginal illustration of the Casino shows how a building's entire facade may be utilized.

There is some tendency toward facade illumination supplementing or eliminating the electric signs with which we are familiar. Where the design of the fa-

The Waldorf ballroom, before the Institute dinner, February 11, 1904

cade is good, this general illumination, through which the building speaks for itself, makes lasting impression upon the public thought. An example, not in the least embellished, is shown on the cover of this report. The effect at the upper cornice is produced by escaping steam made luminous and firelike with red incandescent lamps hidden in the bowl of the flam beau. Though on a narrow street, this illumination draws to the building nightly the attention of thousands from distant Sixth avenue and Broadway. Another instance of building illumination, though in another form, is that of the Pabst Café and Majestic Theatre. Here, the building is partly outlined with torches on the edge of the roof, with striking, though incidental use of signs in various situations.

Something new

Fixtures for interior illumination are perhaps outside the intended limits of this report, yet, at least in remote degree, they are related to decorative lighting. Not always suitable for the place accorded them, when properly placed and designed, they become an excellent decorative possibility. I have therefore included some of the interesting examples brought to my attention.

Interior fixtures

The Cooper-Hewitt mercury vapor lamp promises to come

Midnight—after the dinner—many of the guests had departed

into very general use for advertising purposes. Many may be seen in shop windows where they attract unusual attention, and at least one enclosed sign has been recently erected to use this light. The sign consists of a box enclosed by glass sides, painted to prevent the emission of light elsewhere than through the letters of which the sign is composed. An illustration has been reproduced on one of the following pages.

Hewett light

The Moore vacuum light also has important advertising possibilities. One or two public entrances in New York use it and one of the offices of the New York World receives entire illumination from Moore tubes carried around the cornice of the room. For signs, both lamps may be blown into words or shaped to any desired design.

Moore light

Several of the larger companies are installing signs without charge to the user, though a guarantee is usually asked, based on the number of letters of which the sign is composed or the cost of installation. The rates for current usually remain unchanged—the difference being this guarantee which justifies and insures fair return upon the investment of the Company. To some extent signs may take the place of arc lamps, but the fact should be appreciated that they give advertising as well as light to the consumer and return somewhat more than the average arc lamp revenue. The several reproduced letters on this subject are worth careful consideration.

Free installation

It has seemed desirable to obtain the opinions generally of the membership on this subject, and early in the year a circular letter was issued with that end in view. Many of the replies are reproduced in fac-simile, and will be found worth reading. The "point of view" of a number of users of electric signs has also been obtained and their letters are reproduced. A magnifying glass

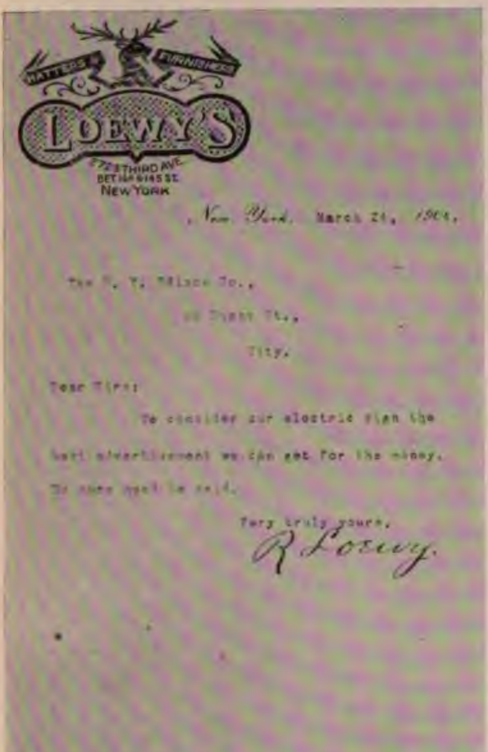
will eliminate any indistinctness resulting from reduction of size.

Decorative and sign lighting, self advertising features of electric light service, may be likened to the advertising pages of a magazine or newspaper, from which the supplying companies and their customers should obtain much mutual benefit. In many instances it will be found necessary to give the matter special attention only at the beginning, after which it will go largely of itself. It is not unlikely that in the future, as justifiable appreciation grows, as much money will be spent for this kind of advertising as is now expended through the press.

Respectfully submitted,

Arthur Williams,

Reporter, Sign and Decorative Lighting.


LOEWY'S

New York

New York, March 24, [illegible]

The [illegible] Co.,

[illegible]

City.

Dear Sirs:

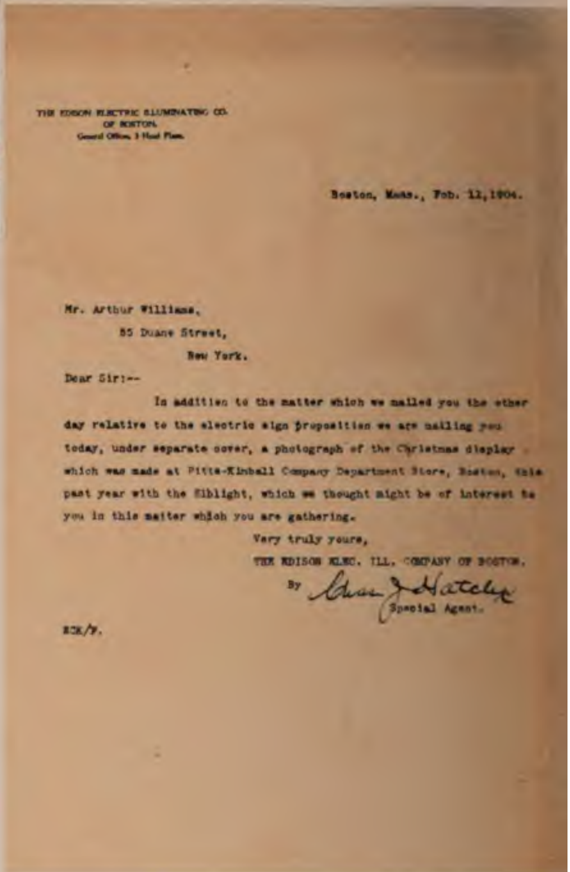
We consider our electric sign the best advertisement we can get for the money. [illegible]

Very truly yours,

R. Loewy.

On Broadway near 30th Street New York

Through the courtesy of The Edison Electric Illuminating Company of Boston



THE EDISON ELECTRIC ILLUMINATING CO.
OF BOSTON.
General Offices, 3 Head Place.

Boston, Mass., Feb. 11,1904.

Mr. Arthur Williams,
85 Duane Street,
New York.

Dear Sir:--

In addition to the matter which we mailed you the other day relative to the electric sign proposition we are mailing you today, under separate cover, a photograph of the Christmas display which was made at Pitts-Kimball Company Department Store, Boston, this past year with the Ediblight, which we thought might be of interest to you in this matter which you are gathering.

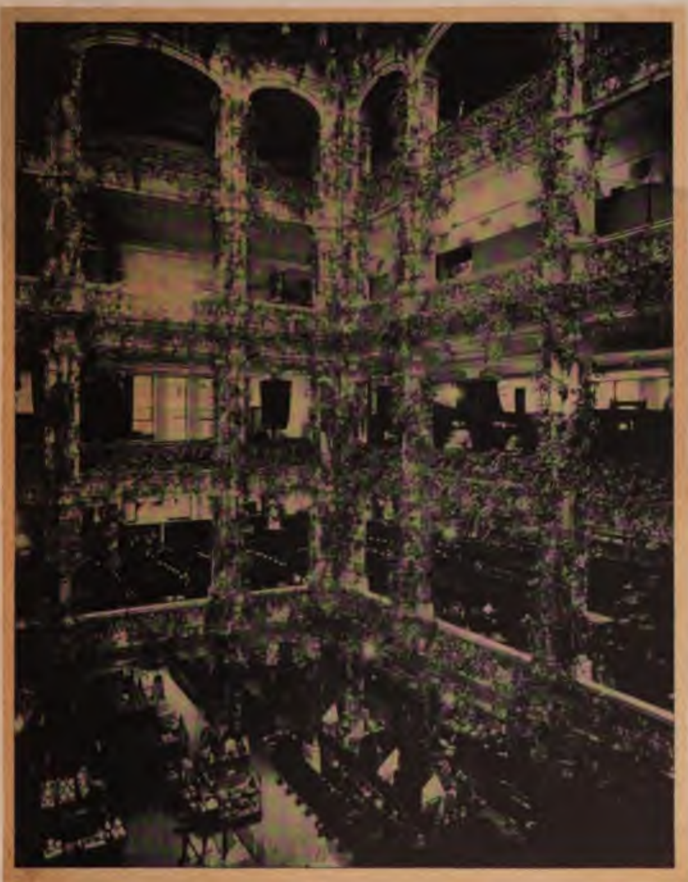
Very truly yours,
THE EDISON ELEC. ILL. COMPANY OF BOSTON.
By Chas. J. Hatch
Special Agent.

ECK/F.

Broadway at 39th Street New York

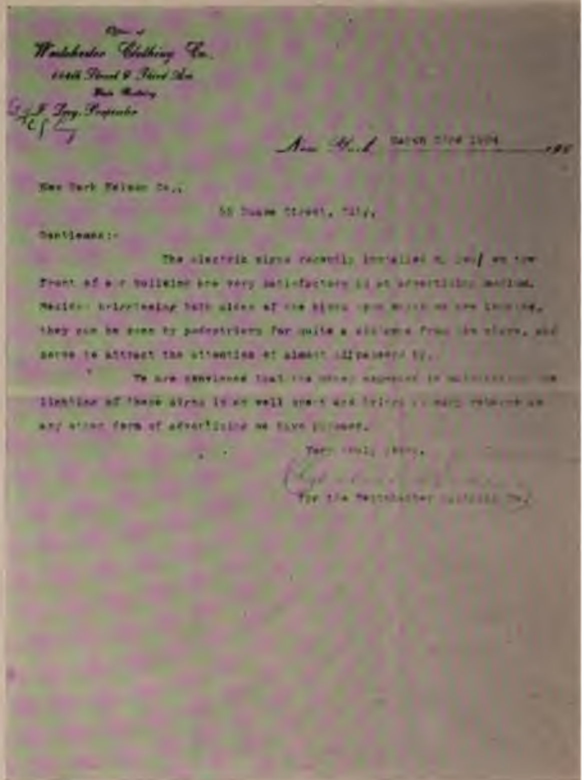
A familiar name

Something new from Boston



Fall opening of the Simpson Crawford Company New York

It speaks for itself



Office of
Westchester Clothing Co.
144th Street & Third Ave.
[illegible]
J. Levy, Proprietor

New York, March 22nd 1904 190

New York Edison Co.,

55 Duane Street, City.

Gentlemen:-

The electric signs recently installed by you on the front of our building are very satisfactory as an advertising medium. Besides brightening both sides of the block upon which we are located, they can be seen by pedestrians for quite a distance from the store, and serve to attract the attention of almost all passers by.

We are convinced that the money expended in maintaining the lighting of these signs is as well spent and brings as many returns as any other form of advertising we have pursued.

Very truly yours,

For the Westchester Clothing Co.

Opening Night on the Williamsburg Bridge, New York, December 19, 1903
An untouched photograph

On Eighth Avenue in New York

MEMORANDUM

FROM
THOMAS J. SHARKEY
[illegible] EAST [illegible] STREET
[illegible]

NEW YORK, March 1 [illegible]

TO New York Electric Co
New York City

Gentlemen—
I have my Electric Sign displayed in front of my place permanently every night since the place is open. I must say it gives me great satisfaction. It's brilliancy could not be matched. It is visible distinctly blocks away. I would not change it for any other means of advertising.
Yours respectfully
Thomas J. Sharkey

Elblight decoration of a ball room

Long Distance Advertising in New York seen a mile in each direction

F. F. PROCTOR'S ENTERPRISES

1904

The New York Edison Company,

55 Duane Street, New York.

Gentlemen:-

In reply to your inquiry requesting my views as to my experience in using electric signs, I beg to state that we were among the first to employ this form of advertising.

The first installation was at our Fifth Avenue Theatre, and that proved so satisfactory that we promptly introduced signs in the other theatres.

Naturally, at night is the time that theatres wish to draw attention to their attractions, and we know of no other method of advertising that is as effective as an electric sign. We believe that our equipments speak for themselves and express our opinion of the electric sign.

Very truly yours,

J. Austin Fynes

5th Avenue Theatre 28th Street Facade

58th Street Theatre

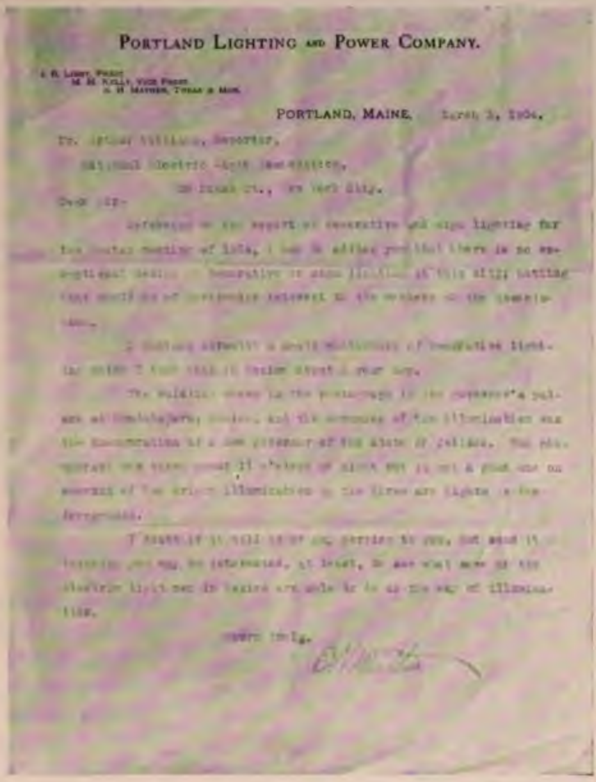
23d Street Theatre

Harlem Theatre, 125th Street

The four Proctor Play Houses in New York to which Mr J Austin Fynes refers in his generous testimonial

Times Square on the East New York City

New York Edison street post and Sign



PORTLAND LIGHTING AND POWER COMPANY.

PORTLAND, MAINE. [illegible]

[illegible]

An excellent example of building illumination from Mexico

EDISON
ELECTRIC ILLUMINATING COMPANY
OF BROOKLYN
General Office, Edison Building

BROOKLYN, NEW YORK Mar.[illegible],1904.

SUBJECT

LOCATION

Mr. Arthur Williams, General Inspector,
New York Edison Company,
83 Duane St., Manhattan,

Dear Mr. Williams:

Replying to your inquiry regarding the increase in our sign business during the year 1903, I beg to say that under our special sign proposition, we contracted and erected during the year 154 signs, 40 of which were individual letter signs and 114 panel signs. The number of lamps in such signs aggregates 10,000, all of which are of 8 candle power and the minimum guarantees in the contracts aggregate $[illegible], per year. Under this special sign proposition, we furnish and erect the sign upon the customer's agreement to pay for the current consumed during a term of not less than two years, subject to a monthly minimum charge commensurate with the cost of the sign. The sign remains the property of the Edison Company, but to cover deterioration and such contract lapses as may occur, we charge off 20% of the cost of such signs each year to operating expenses.

The total Kilowatt hours registered by sign meters for the month of January, 1903 was 11,940, and for the month of January, 1904, 40,401, an increase of 238%. Assuming an average price of twelve cents per Kilowatt hour, our sign revenue for the month of January this year was almost $4,800, as against less than $1,500, for the same month of the previous year.

The total sum expended by the Company for signs furnished during 1903 was about $30,000, and the revenue from such signs figures at least $[illegible],000, annually.

The increase in our sign business during the year has been due almost entirely to such special sign proposition, as without such inducement, the number of signs installed would have been probably not more than 15% of the actual result.

Very truly yours,

Secretary.

Christmas decorations in a Church The Elblight System

Table decoration Accomplished by a General Electric Christmas Tree outfit

OFFICE OF

New Bedford Gas and Edison Light Co.

CAPITAL

New Bedford, Mass. Feb.23,1903

Mr. Arthur Williams,
No.52 Duane Street,
New York, N.Y.

Dear Sir,-

We have to apologize for the omission to answer the letter received sometime since, the fact being that we have nothing in this town that would be new or interesting in the line about which you were inquiring.

There are a limited number of signs , though we have offered special inducements for their installation in the matter of reduced prices.

The sign that seems to do the most talking is used in the advertising of the Glenwood Range. This gives the name of the stove as a constant sign, and with a pointer designates the degrees of heat that different articles of food should be cooked at, the pointer moving from one section of a large circle to the other over the arch, and the degrees of heat being splendidly illuminated as the point proceeds. It is rather an attractive and useful advertising agent, we should think This, however, you no doubt are familiar with.

We have received a copy of the National Convention of last year, in which you so largely exploit the work.

We feel that we have nothing that would be particularly valuable to you in this line.

Yours truly,

President

In Newark N J

George Munk
Shoes.
Dealer in Boots, Slippers & Rubbers
2752 3rd Avenue.

New York 190

Very Respectfully
G. Munk

The old and the new at a New York Bridge
The gas lantern shelters a family of sparrows

Mr Ahearn won by a large majority

In Philadelphia

March 22, 1904.

Arthur Williams, Esq.,
Reporter, Decorative & Sign Lighting,
No. 57 Duane Street, New York City.

Dear sir,-

In re Decorative & Sign Lighting.

Reverting to your favor of December 11, 1903, on the above subject, this Company desires to state briefly that its sign lighting represents some 13,000 incandescent lamps, or about 6,000 16-c. p. equivalent, and is producing a revenue of nearly $6. per annum per 16-c. p. lamp, being double the annual revenue per 16-c. p. lamp on our entire business.

Our sign lighting has increased materially of late, and there is no question but that there is a big field for this class of business, which should be developed. The writer is an advocate of "free signs" on the basis of a monthly minimum guarantee.

Very truly yours,

THE UNITED ELECTRIC LIGHT AND POWER COMPANY,

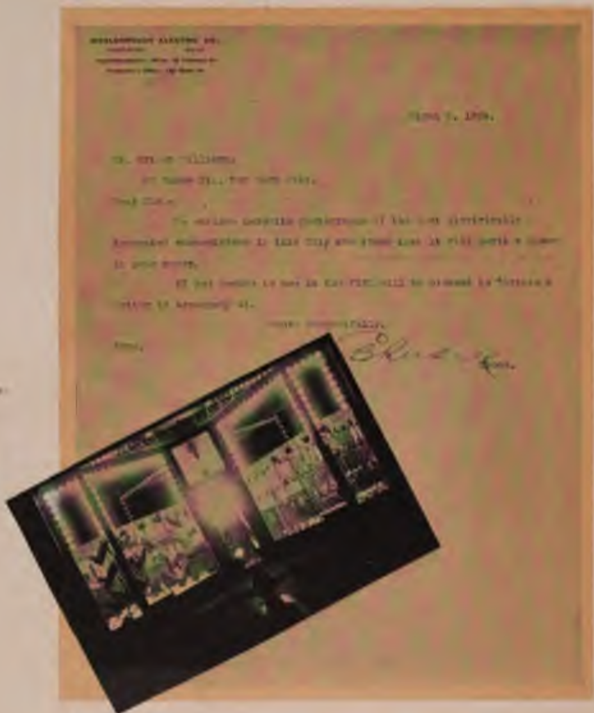
By [signature]

Assistant Secretary.

Harlem advertising making impressions a mile away

The first "Isle of Safety" in New York 23d Street and 5th Avenue

New Political Advertising



An effective Sky Sign in Boston

Street and sign lamp post Central Park New York

A Suggestion in Home Lighting

UNITED ELECTRIC LIGHT COMPANY

SPRINGFIELD, MASS.

Feb. 25, 1904.

Mr. Arthur Williams,

55 Duane Street,

New York City.

Dear Sir,-

In reply to your notice of the 20th inst. regarding report on sign lighting for the association we beg to say that through an oversight your letter of Dec. 11th was not answered.

This company does not do any wiring or sell supplies or novelties and we have as yet had very little business from sign lighting. There are possibly a dozen large ones in all and we get an average of six cents per kilowatt for operating same. We are going to push the sign business from now on and hope to rival New York before very long.

All the fancy decorations for window work etc. are done by the various contractors and we encourage them all we can by [illegible] and prizes for [illegible].

Yours very truly,

RRS/TLH

W. L. Mulligan, Manager.

Enlargement showing the Edison sign on The Times Building New York City

New Orleans Railways Company.
317 Baronne Street.
New Orleans, La.

Office of 2nd Vice President

Feby.23rd.1904.

Mr.Arthur Williams,
#136 Liberty Street,
New York,N.Y.

Dear Sir:-

In answer to your communication and that of Mr.LaRue Vredenburgh from Boston, I beg to state that New Orleans was almost destitute of electric signs until lately and we believe that the introduction and pushing of this method of advertising would prove beneficial to the users.

We have found from actual observation of electric signs that when properly erected, they tend to advance the business of the advertiser,giving him increased trade and larger revenues. The theatres here are all using decorative electrical signs with good results,as it brings boldly forward to the people, the plays that are enacted at the various theatres. For commercial purposes,we have found them very beneficial, and we have one instance on record whereby a commercial college credited the growth of the number of its scholars to the fact of having electric sign, and the number so increased that they were forced to refuse further matriculation until they were removed into a larger building.

Our main days of festivities in New Orleans are at Carnival, and during that period we encourage and promote the use of electricity for decorative purposes. All the clubs and prominent buildings make large displays. I enclose you by this mail several views of various clubs and principal streets which show the artistic designs to which it can be utilized. Our Contracting Department are pushing with zeal, the use of electricity for decorative purposes,offering all inducements to advance this method of advertising,believing it will prove to the best interests of the users.

I regret the delay in answering your letter,but trust that this communication will show the interest which we have in pushing and advancing the use of electricity for signs and decorative purposes.

Yours truly,

[signature]

JHDeG/M

2nd.Vice-President.
New Orleans Railways Co.
N.O.& Carrollton R.R.Light & Pr.Co.

New Building advertising The Times Building Times Square New York City

These are the photographs referred to by Mr B T Burt in the accompanying letter

Chattanooga Electric Co.
CHATTANOOGA LIGHT & POWER COMPANY.
ARC AND INCANDESCENT LIGHTING
AND ELECTRIC POWER

CHATTANOOGA, TENN. Feb'y 23rd, 190[illegible].

Mr. Arthur Williams, Reporter
on Decorative Sign Lighting
N. E. L. Association,
55 Duane Street, New York, N. Y.

Dear Sir:

Replying to your card of Feb'y. 20th requesting matter in regard to sign lighting and decorative lighting I beg to say that there is not much which we can contribute from here.

We have about a dozen of the Federal Electric Company's enamel signs in use and consider them quite profitable and a good advertisement of the electric light as the signs continue to burn on the streets long after most of the stores are closed.

For decorative lighting the Elblight system is used on occasions of balls, coronations at Spring Festivals and garden parties.

I take pleasure in sending you two photographs of an electric illuminated arch gateway to a Spring Festival Exposition held here once a year.

Yours truly,
B. T. Burt
General Manager.

East 14th Street when the Elks came to New York

PENINSULAR ELECTRIC LIGHT COMPANY

Jan. [illegible], 1904.

Mr. Arthur Williams,

55 Duane St., New York.

Dear Sir:

In the matter of decorative and sign lighting, our business the past year has shown a steady increase, about [illegible],000 lamps having been installed which indicates to us a growing popularity for this class of advertising. We have not, however, had any specific cases where we could obtain from the user any direct information as to results, but in several cases customers have expressed their satisfaction in the use of this method of advertising.

We have recently taken up the matter of the [illegible] c.p. lamp for sign work and from new business secured we are satisfied that this lamp will bring us a considerable volume of new business that we could not otherwise secure, besides in some instances retaining signs which there was some probability of being discontinued. The fact that the use of electric signs in all lines of business is on the rapid increase and the retention of all heretofore installed is the only proof we have that the users thereof are satisfied that it is an excellent advertising method and productive of increased trade.

Yours truly,

PENINSULAR ELECTRIC LIGHT CO.

E. F. Phillips

Mr. Williams

JAN [illegible] 1904

Night light effect with the East River Bridge in the distance

Belasco's on 42d Street West of Broadway New York City

At the head of Times—formerly Long Acre—Square New York

An Unsolicited Testimonial

An electric sign containing ten incandescent lamps can be used in New York City two hours daily at a monthly cost of only [illegible], according to the New York Edison Company's Bulletin. Four hours per day cost [illegible] a month. A twenty-lamp sign five hours daily costs [illegible] monthly, and the cost of a fifty-lamp sign for the same period is [illegible]. The ten-lamp sign costs [illegible] and a half cents per day, and need be seen by only eight persons to reduce its cost to the point of a postal card without printing. But there are locations in New York where such an advertisement may be seen by from [illegible] to [illegible] persons [illegible] [illegible] days [illegible].

Meridian Light and Railway Co.

Meridian, Miss. 8/22/04.

Mr. Arthur Williams,
#55 Duane Street,
New York, N. Y.

Dear Sir:—

Referring to your letter and postal card in regard to prepartion of a report on descriptive and sign lights for presentation at the Boston meet 1904.

We have done very little of this work in Meridian but expect to do a great deal in the future. I must ask you to excuse me from making a report on the Meridian situation; you have many large and important cities to hear from, who have a great deal of experience in this descriptive lighting. We shall read these reports with a great deal of pleasure and it will help us a great deal in doing this kind of work in our town and beg leave to sit on the back seat for a while and look on.

Yours very truly,

J. H. Gibson
Sec'y. & Treas

Designed for a "Den"

The Edward Cooper House
at Washington Square
and Fifth Avenue
Showing the
Twin Street Lamps

SKOWHEGAN ELECTRIC + LIGHT + COMPANY.

C. J. ABBEY, Superintendent and Electrician.

Skowhegan, Me. March, 1, 1904.

Mr. Arthur Williams, Reporter,
Decorative & Sign lighting,
New York,

Dear Sir:-

In reply to youre of Dec. 11th, relative to Sign and Decorative lighting, will say, as yet I have not had the oppitunity to determine the value of this class of lighting for our customers, as we have none of any amount here, our stores are all well lighted with Electricity, some with attractive Illuminated show-windows, yet our Merchants do not take to sign and special decorative lighting, as they figure that the outlay and cost of maintenance would be more than their gain, yet I am in hopes to induce at least a few of them to try it this season, if I can succeed in getting them started possibly it will terminate in an epidemic as the modern Illumated show-case has, however from a general standpoint on the line of progress of Merchants attractions, I consider sign and decorative lighting greatly to their advantage.

Very truly,
C. J. Abbey Supt

For the Christmas Tree, Table and Other Electrical Decorations
The General Electric Company

ELMIRA WATER, LIGHT AND RAILROAD COMPANY.
OF ELMIRA, N. Y.

ELMIRA, N. Y., Feb. 27, 1904

Arthur Williams,
55 Duane Street,
New York.

Dear Sir:--

Your favor of the 25th inst. received. Would say in reply that we have no photographs which would be of use to you. We have just recently taken up a system of pushing our business for decorations and signs and are doing some free work at the present time in order to get a start in this line of business, but having not yet advanced far enough to give you a letter which would be of use to you.

Yours truly,

W. W. Cole

Vice Pres. & Gen. Mgr.

Christmas Tree lighting — very effective

Explained in the letter attached from Mr Arthur B Lisle

NARRAGANSETT ELECTRIC LIGHTING CO.

[illegible]

Very respectfully,

Arthur B. Lisle.

Decorative Wall Bracket

Broadway at 40th Street—Storm Swept

A Cooper-Hewitt Sign Effect

Bird's-Eye View of Luna Park, Coney Island

Electric current supplied by the Brooklyn Edison Company

Reproduced through the courtesy of "The Brooklyn Edison"

Fifth Avenue at 34th Street, New York

APPENDIX C

REMOTE CONTROL OF ELECTRICAL APPARATUS

BY

WILLIAM H. COLE

(This paper was read at Tuesday's afternoon session, directly after that of Mr. Eastman, but owing to an oversight in printing it was omitted and the error not discovered in time to insert it in its proper place.—EDITOR.)

REMOTE CONTROL OF ELECTRICAL APPARATUS

The object in presenting this paper to this association is to bring out and stimulate interest in various methods of controlling apparatus used in the regulation, conversion and distribution of electricity. It will deal more particularly with methods, both proposed and actually used, for the control of constant-current apparatus where cost and convenience, or both, require that such apparatus be placed at points remote from the generating or operating station.

Of course it is possible to locate all such apparatus in the operating station under the manual control of the operators, where all operations incident to the starting and stopping may be performed by the attendants, and where the necessary remedies may be applied in cases of trouble. This course, looked at from an engineering standpoint, may be the best to pursue, but for commercial reasons it must at times be departed from.

Generally speaking, in laying out a system of distribution, simplicity is aimed at, and we try to reduce the number of conductors in our trunk lines to the smallest possible number consistent with the demand for continuous service. One of the main objects in locating constant-current apparatus in substations is to produce this result, and in so doing we not only do away with the maintenance of a large number of high-tension, low-current wires, but provide room for duplicate feeders to the substation.

While locating such apparatus in substations relieves us of the burden of maintaining a system of distribution where all circuits start from the generating or operating station, we must not lose sight of the fact that such location presents an opportunity for a better division of secondary circuits with a corresponding reduction in potential. Supposing that for economic reasons it is considered advisable to locate apparatus of this nature in a substation situated at some distance from the source of supply, this question naturally arises: "What method of control shall be used?" As for several reasons it is not desirable to switch constant-current

apparatus on to a system unless the relative position of the fixed and movable coils is such that nothing greater than the normal current may flow,—particularly if incandescent lighting forms a part of the load—the question naturally suggests but a choice between two methods, namely, manual or automatic control.

Manual control suggests an operator on duty at starting time and possibly all the time apparatus is in operation.

Automatic control, to be effective, must produce substantially the same results as manual control from the time the current is switched on to the apparatus until it is switched off.

Taking up the most important application of remote control, I will describe a system of controlling constant-current transformers connected to circuits of arc or incandescent lamps arranged in single or multi-circuits.

In applying this method we first find it necessary to use a special counterweight whose weight and volume bear a certain relation to each other, which necessity I think will be obvious after a description is given of the workings of the system.

Referring to the diagrammatical representation of a constant-current transformer of the two-coil type, Figure 1, the means for controlling and the operation is as follows:

A represents a partial view of the casing inclosing the apparatus to be controlled; *Q*, an adjustable arc carrying the adjustable counterweight *W*; *p1* and *p2* represent the primary mains, and *s1* and *s2* the secondary mains leading to the lamp circuit; *14* and *15* represent two tanks adapted to contain oil or some other suitable fluid.

P represents a pump of any suitable construction driven by a motor (not shown in sketch) supplied with current through the secondary leads from the small transformer *T*. The suction is represented by *9*, and *10* is the discharge of the pump *P*. *F* is a float responsive to the variation of level of the liquid in the tank *15*, and is carried by the arm or lever *17*, pivoted at *16*, and operates the switch *18*.

Connected in series with the lamp circuit is a solenoid *13* controlling the vertical movement of the core *12*, which in turn operates the valve *V* in the lower end of the tank *14*.

It is, of course, to be understood that this sketch refers to apparatus in which a reduction of the weight *W* normally produces an increase of current in the work circuit.

In adjusting a constant-current transformer or reactive coil controlled by this method it is necessary to make the counterweight *W* sufficiently heavy to slightly more than balance the weight of the moving parts of the apparatus to be controlled; or, in other words, the weight must always take the lowest or no-load position with no current on. This adjustment is of course made with the weight floating in air.

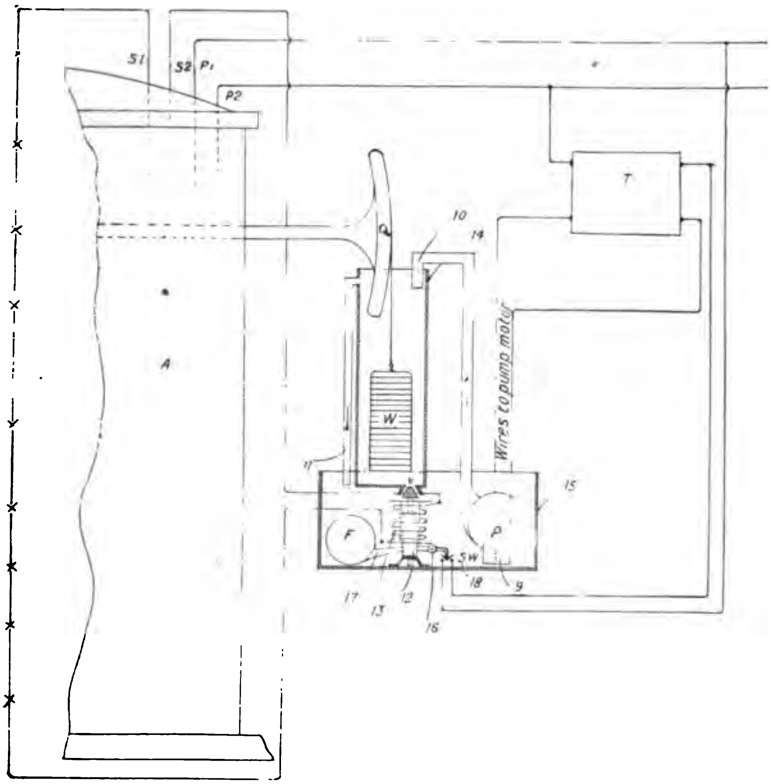


Fig. 1

The next adjustment is to change the volume of *W* without changing its weight, so that it will regulate for the current desired. This adjustment is made with the weight immersed in oil.

It is evident that after these adjustments are made the weight and volume of *W* is such that the transformer or coil

will regulate for constant current with the tank *14* full of oil, and will assume the no-load position when tank *14* is empty.

At starting, tank *14* is empty, valve *V* is open, switch *18* is closed, and tank *15* is filled with oil to a suitable height.

If circuit containing translating devices is closed the solenoid *13* is energized, core *12* is drawn up, closing valve *V*. Switch *18* being already closed, transformer *T* supplies current to the motor driving pump *P*, which draws oil from tank *15* and forces it into tank *14*. This continues until the level of the oil in tank *15* is brought low enough to operate float *F* and switch *18*, which opens the primary of transformer *T*, causing the motor and pump to stop. At this point the oil has reached a level in tank *14* sufficiently high to entirely immerse *W* through its entire range of travel. *W* has meanwhile gradually taken a position depending upon its adjustment and the load and regulates for constant current.

When shutting down the lamp circuit, the current is switched off from the apparatus, and the solenoid *13* is immediately de-energized, allowing valve *V* to open by gravity, which allows the oil to flow into tank *15*. As is very readily seen, this action causes *W* gradually to take its no-load position, and switch *18* closes, thus leaving apparatus prepared for the next switching on of current. It will be observed, of course, that in case valve *V* should leak during the operation of apparatus, the float switch would automatically close and oil would be pumped back into tank *14* to supply leakage.

This system has also been worked out for the control of transformers of the large sizes where more than one secondary coil, balanced one against the other, is used; but it is not deemed necessary to explain it here, as the same general principles apply..

A sketch showing the arrangement of tanks and valves necessary for the control of these large transformers is herewith shown, Figure 2, and from it the operation may be deduced.

In connection with these methods of remote control it is desirable and profitable to use some method of disconnecting circuits that may for any reason accidentally open.

By using automatic absolute series cut-outs we not only provide means for keeping all lamps burning that are not

on the faulty circuit, but by absolutely disconnecting the faulty circuit or loop from the rest of the secondary system we remove a source of considerable danger to the public from fallen wires. This cut-out is arranged to be thrown in cases of open circuits by means of a spring and trip, which trip is operated by a solenoid or magnet. This magnet or solenoid, as the case may be, is connected to the secondary

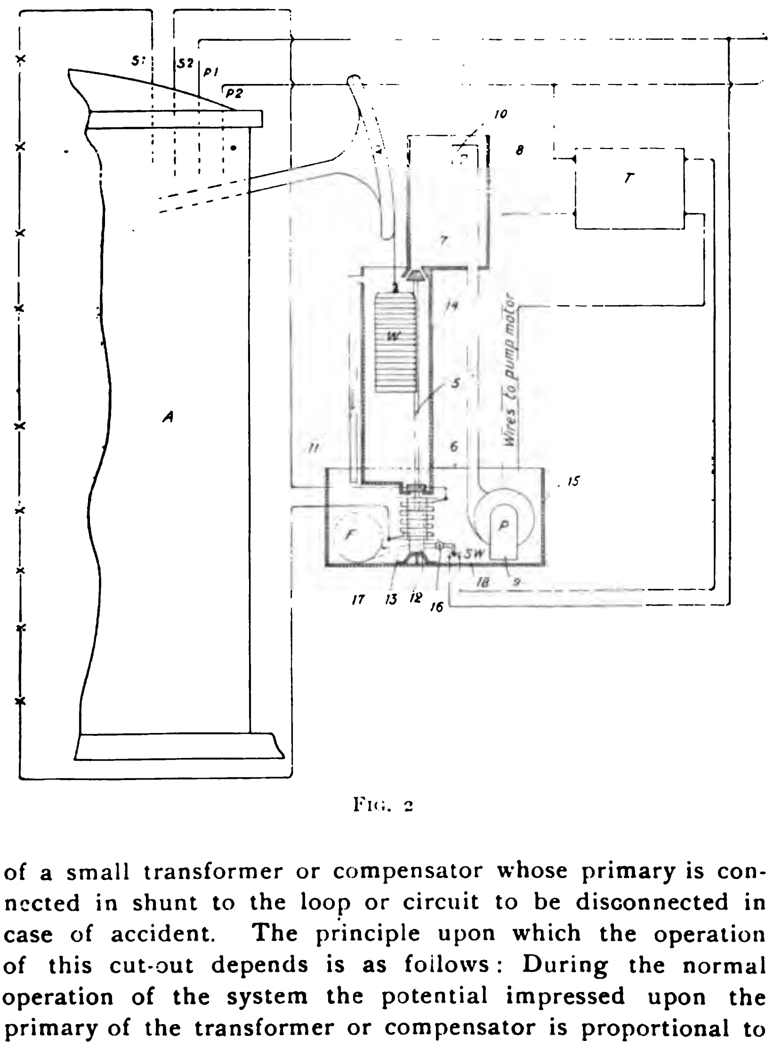


FIG. 2

of a small transformer or compensator whose primary is connected in shunt to the loop or circuit to be disconnected in case of accident. The principle upon which the operation of this cut-out depends is as follows: During the normal operation of the system the potential impressed upon the primary of the transformer or compensator is proportional to

number of lamps burning on the loop beyond the cut-out. The core or armature of the solenoid or magnet is so adjusted that the normal secondary potential of the transformer or compensator is not sufficient to trip the cut-out. If, however, the loop or circuit should open, there is immediately impressed upon the terminals of the small transformer the full potential of the constant-current transformer secondary. This same ratio of increase also appears at the terminals of the tripping coil, which is so adjusted that it immediately trips the cut-out. This cuts out the open loop and re-establishes the continuity of the circuit through the remaining lamps.

It is obvious, of course, that the field of usefulness of this device is not limited to indoor or substation use. It may be, in certain cases, desirable to cut in reactance or counter electromotive force in place of the disconnected circuit, which may readily be accomplished with the same apparatus.

Of course it is well known that remote control of various kinds of apparatus has been accomplished by the use of auxiliary wires operating electro-magnetic switches or other electro-mechanical devices that by means of levers, weights, etc., may be made to perform certain duties.

It is fully appreciated by the writer that remote control of electrical apparatus to be commercially successful must be as simple mechanically as possible, and must require no auxiliary wires from the operating station, clock-work devices, time switches, or kindred apparatus.

Oil as an agent for producing the necessary changes in the effective weight of the counterbalances, being a flexible medium and easily handled by a free-acting pump, tends to give a reliability to the performance of the apparatus which would not be possessed by any mechanical device calculated to produce the same results.

The development of a successful automatic series cut-out supplies a growing want for a device of this character, more particularly felt since the advent of the high-tension series alternating-system of lighting.

The system described in the foregoing paper is the product of considerable thought and experiment, and is calculated to produce the desired results with the minimum of mechanical and electrical complexity.

OKONITE

TRADE MARK.

For underground, aerial, submarine, switchboard and, in fact, general use, where an insulated wire is required, it has no equal.

This is the unanimous opinion of Electrical Engineers and Station Managers all over the country, after years of use under the most exacting conditions.

ONLY ONE GRADE MANUFACTURED AND THAT THE BEST

Therefore, in buying "Okonite" no chances are taken of being supplied with an inferior article to meet a "cut" in price.

A fact which cannot be too strongly emphasized is that a low grade of wire is not only a source of danger and an annoyance, but, in the end, of far greater expense than a high grade.

OKONITE TRADE MARK.

MORAL:
USE
"OKONITE"

OKONITE TRADE MARK.

PRICES ON APPLICATION

Manufacturers also of Okonite Tape, Manson Tape, Candee Weather-proof Wires and Candee Patented Pot Heads.

THE OKONITE COMPANY
LIMITED
253 BROADWAY, NEW YORK

MOTORS FANS

Direct Current

GENERATORS

FOR LIGHT AND POWER

Superior Design and Construction

Our generators are built for high class service, and range in size up to 1000 k.w. They are modern in every respect and unequaled in commercial value. :: :: :: ::

SPRAGUE

ELECTRIC COMPANY

NEW YORK

HOISTS CONDUITS

THE ELECTRIC STORAGE BATTERY COMPANY

Philadelphia

MANUFACTURER OF THE

"Chloride Accumulator"

FOR

Central Station Lighting and Power Plants

Isolated Lighting and Power

Electric Railway Power and Sub Stations

Telegraph, Fire Alarm, Telephone, Etc.

Send for Descriptive Bulletins and Price Lists

.... SALES OFFICES ....

NEW YORK
100 Broadway

BOSTON
60 State St.

CHICAGO
Marquette Bldg.

ST. LOUIS
Wainwright Bldg.

CLEVELAND
Citizens' Bldg.

SAN FRANCISCO
Rialto Bldg.

PHILADELPHIA
Allegheny Ave. & 19th St.

CANADA
Canadian General Electric Co., Ltd.
Toronto

HAVANA, CUBA
G. F. Greenwood, Manager
34 Empedrado St.

HERBERT S. POTTER

Electrical Engineering
and Contracting

24 COMMERCE ST., BOSTON, MASS.

Edison Light work a specialty

ATLANTIC INSULATED WIRE & CABLE CO.

WIRES AND CABLES

FOR SUBMARINE, AERIAL, UNDERGROUND
AND INTERIOR USE

FACTORY
STAMFORD
CONN.

120 LIBERTY STREET
NEW YORK CITY

WESTINGHOUSE CHURCH KERR & COMPANY

ENGINEERS AND CONSTRUCTORS

NEW YORK

The "Big Reliable"

5000 horsepower Allis-Chalmers Engine

and Bullock Generator

World's Fair, St. Louis

Supplying current for the Decorative Lighting of the

WORLD'S FAIR, ST. LOUIS

The Best Workmanship The Best Performance

Designed 1903 Shipped from our Works January, 1904—37 Carloads

Steam first turned on April 20th, 1904 Operated perfectly ever since without costing a cent for repairs

The world-renowned Decorative Lighting of the St. Louis Exposition Buildings and Grounds started April 29th, 1904, this Engine and Generator carrying the load then and ever since

Night after night carrying 1500 horsepower overload, running cool and steady

The Engineering Triumph of the World's Fair

Allis-Chalmers Co.

Milwaukee, Wis., U. S. A.

Canadian representatives, Allis-Chalmers-Bullock, Ltd., Montreal

Bullock Motors

for driving Machine Tools

Bullock 6 horsepower Type "N"
Motor Driving 42 inch Boring Mill
at World's Fair, St. Louis
Controlled by Bullock Multiple Voltage Balancing Set

Direct and Alternating Current Apparatus

The

Bullock Elec. Mfg. Co.

CINCINNATI, O.

Canadian representatives, Allis-Chalmers-Bullock, Ltd., Montreal

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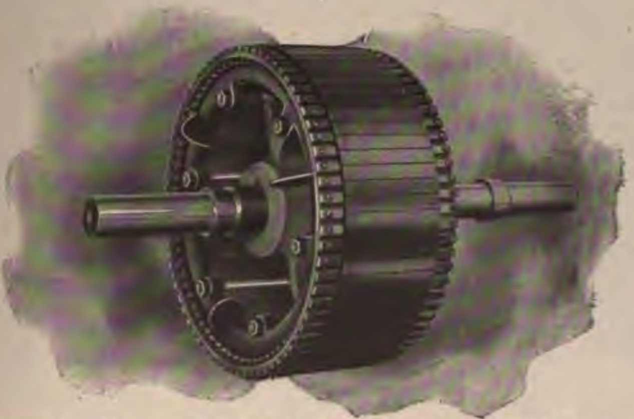

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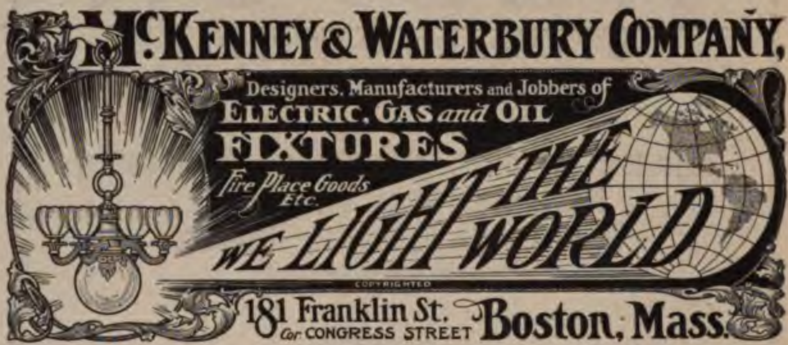

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